U.S. DEPARTMENT OF THE INTERIOR
SUBMISSION TO

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD
IN RESPONSE TO
ORDER NO. WQ-88-7

Effectiveness of Filling Ephemeral Pools at Kesterson Reservoir

Kesterson Program Upland Habitat Assessment

Kesterson Reservoir Final Cleanup Plan

April 1, 1989

U.S. Department of the Interior

EFFECTIVENESS OF FILLING EPHEMERAL POOLS

AT

KESTERSON RESERVOIR

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Introduction

The State Water Resources Control Board, in Order No. WQ 88-7 issued July 5, 1988, directed the Bureau of Reclamation (Reclamation) to fill all ephemeral pool areas, on a priority basis, to six inches above the rising ground water by January 1, 1989. The objective of the Board's Order was to eliminate surface pools formed by rising ground water prior to the 1988-89 winter season. This report presents a summary of the filling activities at Kesterson Reservoir and an evaluation of the effectiveness of the filling in the elimination of ground water pools at the Reservoir.

Description of Filling Operation

Contract Summary

A letter contract was issued to Dutra Construction Co., Inc. of Rio Vista, California on July 6, 1988. The contract specified the filling of an estimated 589 acres with an estimated 723,400 cubic yards of material. Ephemeral pools were to be filled on a pond priority basis, with ponds 1, 3, 4, and 6 to be filled first, followed by ponds 5 and 7, and then the remainder of the ponds. The contract required completion of the scheduled work by December 1, 1988 and included incentive payments, based on volumes of material imported, for early completion of the work.

As the work progressed, modifications were made to the original contract. When the contractor demonstrated that work could be completed by the scheduled deadline, the requirement for filling based on pond priority was eliminated and the contractor was allowed to place fill in the most efficient manner. A neighboring landowner requested that material be removed from his land to benefit his waterfowl management activities. After determination by the Fish and Wildlife Service and Reclamation that such borrow operation would benefit wildlife, that the material was suitable for use in the Reservoir, and that use would result in a cost savings to the Government, the contractor was allowed to use borrow material from this site. Modifications to the original contract were also made to provide for discing of 345 acres of cattails prior to filling, maintenance work on Gun Club Road, provision of a special bus to safely transport children to and from school, and revision of the quantity of material needed to complete filling of the Reservoir.

Hauling of material was completed on November 16, 1988, and the contract was complete on December 16, 1988. Total contract costs were approximately 6.5 million dollars.

Sources and Volume of Fill

Fill material placed in the Reservoir was obtained from three sources: the interior and exterior dikes at Kesterson Reservoir, spoil material from the Delta-Mendota Canal, and the Fields Gun Club.

1. ONSITE BORROW

The contractor commenced moving heavy equipment to Kesterson Reservoir on July 18, 1988. The contractor used five Caterpillar scrapers for the onsite borrow operation. A total of 195,526 cubic yards was excavated from the interior and exterior dikes at Kesterson Reservoir. Exterior dikes were left at an elevation sufficient to provide 100-year flood protection for the site. The onsite borrow excavation was completed on August 29, 1988.

2. DELTA-MENDOTA CANAL SPOIL BANKS

Reclamation and the Fish and Wildlife Service jointly completed environmental evaluation and documentation of the selection of an offsite borrow location for fill material. The selected site was between Milepost 52-56 on the east bank of the Delta-Mendota Canal. Soil samples were collected from the selected borrow material and the soil data reviewed for suitability as fill material by Reclamation, Fish and Wildlife Service, and the U.S. Geological Survey. Selenium levels in 11 samples taken of the proposed fill material were 0.2 ug/g or less. The conclusion of all reviewers was that the material was suitable as fill material for Kesterson Reservoir. The contractor commenced importation of material from the Delta-Mendota Canal on August 3, 1988.

The contractor used 30 to 80 double trailer, bottom dump trucks in its hauling operation. The contractor's average production rate was about 11,500 cubic yards per working shift. A total of 811,529 cubic yards of material was imported from the Delta-Mendota Canal borrow site. Offsite borrow was complete on November 16, 1988.

3. FIELDS GUN CLUB

A neighboring landowner approached the Bureau and the contractor offering fill material in exchange for excavation on the Fields Gun Club west of the southern part of Kesterson Reservoir. The excavation was intended to improve waterfowl management on the club. The land is under the Federal Conservation Easement Program and the excavation proposal was reviewed and approved by the Fish and Wildlife Service. Samples of the proposed material were taken and determined to be suitable for use as fill material at the Reservoir. Selenium levels were .23 ug/g or less in all samples. The contractor submitted a value engineering change proposal under the Federal Acquisition Regulations and use of the

material was approved. A total of 42,340 cubic yards was excavated from the Fields Gun Club in the two week period ending September 23, 1988, and placed in Pond 4 of the Reservoir.

Fill Placement

A total of 1,050,437 cubic yards of fill material was placed in the low lying areas at Kesterson Reservoir. Table 1 lists the following information for each pond: volume (cubic yards), final grade elevation, approximate areas covered, and average fill depth.

The contractor achieved the target final grade elevation in all ponds. A post filling topographic map of the Reservoir is under preparation and is expected to be complete by mid-April.

TABLE 1. KESTERSON RESERVOIR POND FILLING

POND NUMBER	VOLUME CUBIC YARDS	FINAL GRADE ELEVATION	APPROXIMATE ACRES COVERED	AVERAGE FILL DEPTH (FEET)
1	176,068	75.00	90	1.2
2	20,040	74.00	24	.5
3	34,355	74.00	33	.6
4	120,242	74.00	55	1.3
5	191,814	73.50	89	1.3
6	85,538	73.50	63	.8
7	63,416	73.50	57	.7
8	67,840	73.50	76	.6
9	84,063	72.50	67	.8
10	63,416	72.50	68	.6
11	135,681	71.50	68	1.2
12	7,964	70.50	27	.2
TOTALS	1,050,437		713	

* Average fill depth determined by dividing the area covered by the volume of material.

Dust Control and Road Repair

The haul roads, fill areas and borrow sites were patrolled regularly by water trucks to provide dust suppression during the construction operation.

The following equipment was used to control dust at Kesterson Reservoir: two 3,800-gallon water trucks and one 8,000 gallon waterpull. Water was supplied from two ground water wells located in the west bank of the San Luis Drain, adjacent to Pond 7 of the Reservoir.

A 3,800 gallon water truck was used to control dust at the Delta-Mendota Canal borrow site. Water for the borrow operation was pumped from the Delta-Mendota Canal. A separate spray bar was utilized to dampen the loaded truck trailers before they left the borrow sites to travel on State and County roadways. This helped control dust along the truck haul route and adjacent farms.

The contractor applied a total of 23,297,000 gallons of water for dust control, not including water applied on Gun Club Road.

Following commencement of offsite borrow hauling from the Delta-Mendota Canal, Merced County's Gun Club Road deteriorated under the pressure of heavy truck traffic. The contractor replaced the oil surface roadway with Class II aggregate base and provided daily maintenance and dust control during the hauling activities.

Three 3,800 gallon water trucks applied water on Gun Club Road. Water for dust control on Gun Club Road was purchased by the contractor from the Central California Irrigation District.

Following completion of hauling activities, Reclamation and Merced County defined the work required to restore Gun Club Road to its original condition. By agreement with the County, the Bureau provided a lump sum payment to the County and the County will complete necessary repairs to Gun Club Road.

Environmental Compliance Activities

Reclamation and the Fish and Wildlife Service jointly conducted environmental evaluation and documentation for the selection of offsite borrow locations. A fox den, potentially that of the endangered San Joaquin kit fox, was found on the west spoil bank of the Delta-Mendota Canal borrow site. Borrow operations were therefore restricted to the east side of the canal where no evidence of kit fox use was found. Because the San Joaquin kit fox occurs throughout the area and is subject to road mortality, all truck and equipment operators were required to read and sign a kit fox information sheet. Personnel were requested to report any fox sightings and required to report any road killed kit fox. No kit fox mortality was reported during the construction period.

Prior to use of the Fields Gun Club borrow site, an archeological survey was conducted to determine the presence of any archeological or cultural resources. None were detected and none were subsequently uncovered during the excavations.

The Delta-Mendota Canal borrow areas have been groomed and reseeded with a mixture of grasses. As agreed during consultation with the Fish and Wildlife Service prior to borrow operations, two artificial kit fox dens will be placed in suitable habitat. Sites have been selected and the dens will be placed in the near future.

Health and Safety

A certified industrial hygienist from Safety Specialists, Inc. developed a Health and Safety Plan from dust sample data and personal air monitoring conducted on July 27, 1988. The industrial hygienist reported that workers were not exposed to hazardous levels of selenium. To ensure that the onsite personnel did not ingest selenium while eating, the contractor transported field employees to a special facility where they were assured of eating in a dust free environment.

A second site visit by the industrial hygienist to gather samples and review construction activities occurred on September 29, 1988. The second report indicated that there was no threat of exposure to hazardous levels of selenium.

In September, the contractor entered into an agreement with the Gustine School District authorities to provide a special bus to safely transport school children to and from school. This school bus was to reduce exposure to the heavy truck traffic for children along the contractor's haul route.

Hydrologic Conditions 1988-89

Ground Water

Every year the water table underlying Kesterson Reservoir has risen and fallen in response to numerous factors, including: flooding, both the former ponds within Kesterson Reservoir as well as the surrounding seasonal wetlands; precipitation; evapotranspiration; and ground-water pumping. The 1988-89 wet season at Kesterson Reservoir differed from the past 18 years in two important ways which affected ground water ephemeral pool formation. First, there was no intentional application of surface water within the Reservoir during or prior to the wet season. Second, a large portion of the original Reservoir soil surface was covered with fill material.

Cessation of intentional applications of surface water at the Reservoir has had two immediate effects on formation of ephemeral pools. The most obvious effect is the lack of pooling due to leakage through check gates and berms separating wet from dry ponds. A second important effect of the termination of intentional flooding at the Reservoir is that of eliminating the

influence of flooding on water table elevations in the immediate vicinity of the intentionally flooded ponds.

Past records indicate that seasonal fluctuations of the water table were on the order of 5 feet, with the highest elevations occurring in the period between February and March. Previous estimates, based on water-level data collected in 1970 and 1971, prior to intentional flooding within Kesterson Reservoir, indicated that in a typical water-year the water-table would rise above the original ground surface of the Reservoir, creating several hundred acres of ephemeral pools. The objective of filling the low-lying areas of the Reservoir was to raise the elevation of the ground surface above the maximum height of the water-table. Water level data are now available for the current wet season and provide a basis for determining if the filling operation was successful in meeting its objective.

Water-level data were collected from 300 wells in and around Kesterson Reservoir during January 31 to February 2, 1989. A water-table map for this period is provided in Figure 1. A comparison between the elevation of the average water-table and the engineering specifications for fill elevation is provided on a pond-by-pond basis in Table 2. As indicated by the last column in this table, the average distance between the fill surface and the water table ranges from 2 to 5 feet. Spot checks at weekly intervals between February 1 and March 29, indicate that the water-table peaked about March 1. The water-table rose an additional 1 foot in Pond 1, 1/2 foot in Ponds 3 and 4, and almost imperceptably in the northern ponds.

The filling operation was designed to raise the ground surface to at least 1/2 foot above the average annual maximum height of the water-table. Data from the current wet season indicate that this criterion has been satisfied in all of the ponds. No ephemeral pools formed by rising ground water have occurred at Kesterson Reservoir over the current season. In addition, there is a safety margin of several feet between the water-table and ground surface in the majority of the ponds. A hydrologic assessment of the water-table elevations over the past years indicates that the water-table is unlikely to rise above the ground surface. Anticipated conditions during future years are described in greater detail later in this report.

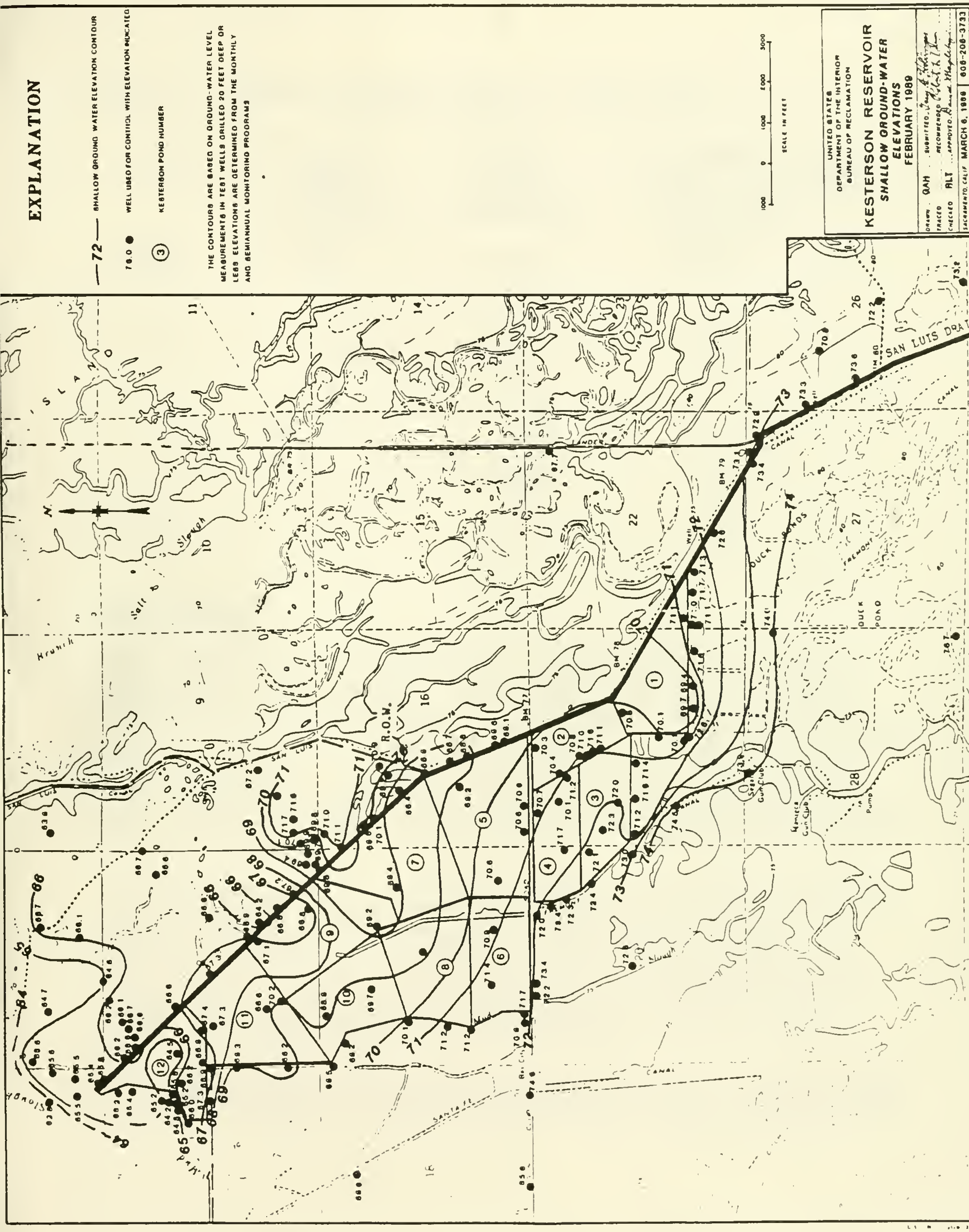
EXPLANATION
SHALLOW GROUND WATER ELEVATION CONTOUR
WELL USED FOR CONTROL WITH ELEVATION INDICATED
KESTERSON POND NUMBER
THE CONTOURS ARE BASED ON GROUND-WATER LEVEL MEASUREMENTS IN TEST WELLS DRILLED 20 FEET DEEP OR LESS. ELEVATIONS ARE DETERMINED FROM THE MONTHLY AND SEMIANNUAL MONITORING PROGRAMS
SCALE IN FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KESTERSON RESERVOIR
SHALLOW GROUND-WATER
ELEVATIONS
FEBRUARY 1989
SACRAMENTO, CALIF.
MARCH 6, 1989
SAN LUIS DRAIN
DUCK PONDS
DUCK POND
CANAL
Salt Slough

Figure 1

TABLE 2. KESTERSON RESERVOIR DEPTH TO WATER TABLE

POND NUMBER	AVERAGE WATER TABLE ELEVATION February 1, 1989 (FEET)	TARGET FILL SURFACE ELEVATION (FEET)	DIFFERENCE BETWEEN TARGET FILL SURFACE AND AVERAGE DEPTH TO WATER TABLE February 1, 1989 (FEET)
1	70	75	5
2	70.5	74	3.5
3	72	74	2
4	72	74	2
5	70	73.5	3.5
6	71.5	73.5	2
7	69.5	73.5	4
8	70	73.5	3.5
9	68	72.5	4.5
10	69.5	72.5	3.0
11	68	71.5	3.5
12	66	70.5	4.5

Surface Water

The filling operation at Kesterson Reservoir was motivated by concern over biotic exposure to selenium through the highly contaminated ephemeral pools that formed when the water table rose above the ground surface. As discussed in the previous section, no such pools have been observed at the Reservoir during the 1988-89 season. However, as anticipated, numerous shallow puddles formed on top of the fill after rains. These surface puddles formed where there are slight topographic depressions and/or where soils were heavily compacted by equipment during the filling operation.

Following rainfall events, it was estimated that surface puddles covered up to about one percent of the filled Reservoir area. No significant ponding was observed on undisturbed (unfilled) soil surfaces at the Reservoir. Within a matter of a few days following the rainfall event many of the surface puddles had disappeared. However, in some areas surface puddles persisted through subsequent rainfall events creating pools that were present for essentially the entire winter.

Where puddles were observed to be persistent, i.e., lasted longer than about a week to ten days after rainfall events, the pool was staked and surveyed for future identification and location. The

largest of these rainwater pools was located in the former Pond 2 and varied between about 1/3 and 1/4 acre in size. In total, these 'persistent' pools encompassed a total of about 3 acres, or about 0.5 percent of the filled area. Water quality and biological activity in the surface puddles are discussed in the Upland Habitat Assessment Report which accompanies this document.

Anticipated Future Hydrologic Conditions

Ground Water

As described above, early in February the water-table was from 2 to 5 feet below the ground surface, indicating that ponding at the Reservoir due to rising ground water had not occurred. The seasonal water-table rise is primarily caused by application of surface water to the surrounding duck clubs, which comprise approximately 18 percent of the area in a 124 square mile region centered on Kesterson Reservoir (Mandle, R.J. and Kontis, A.L., "Directions and Rates of Ground-Water Movement in the Vicinity of Kesterson Reservoir, San Joaquin Valley, California", US Geological Survey Water Resources Investigations Report 86-4196, 1986). Several other factors may affect the height of the water-table, including ground water pumping, annual precipitation, and long-term trends in water use patterns in the valley. An effort is underway to develop a detailed hydrologic model of the area that will assess each of these factors and provide a calibrated model of the regional water-table in the vicinity of Kesterson Reservoir. This model is not anticipated to be complete until late summer of this year. However, historic water-level and rainfall data have been reviewed to provide a preliminary assessment of the anticipated hydrologic conditions at the Reservoir.

As stated above, the primary cause of the seasonal increase in the water-level is the flooding of the nearby duck clubs. An estimated 2 to 3 acre-feet/acre of water is applied in September-October to flood the diked enclosures of the duck clubs (Dan Severson, USFWS, San Luis National Wildlife Refuge Conplex, personal communication). A substantial fraction of this water seeps into the underlying aquifer or evaporates leaving the remaining water to create ponds with an average depth of about 1 foot. Over the winter, additional water is applied to maintain pond levels. In early spring the duck clubs are drained over a period of about a month, leading to decreased seepage rates and a corresponding drop in the elevation of the water-table in the surrounding areas. Over the summer, evapotranspiration and internal drainage dry the soils until the next flooding event. As illustrated in Figure 2 the water-table closely follows these events. Within the Kesterson area, during the 1988-89 wet season, flooding the duck clubs created water-level increases of 2.5 to 5 feet, with the largest increases occurring immediately adjacent to flooded duck club lands, i.e., Ponds 3, 4, and 6.

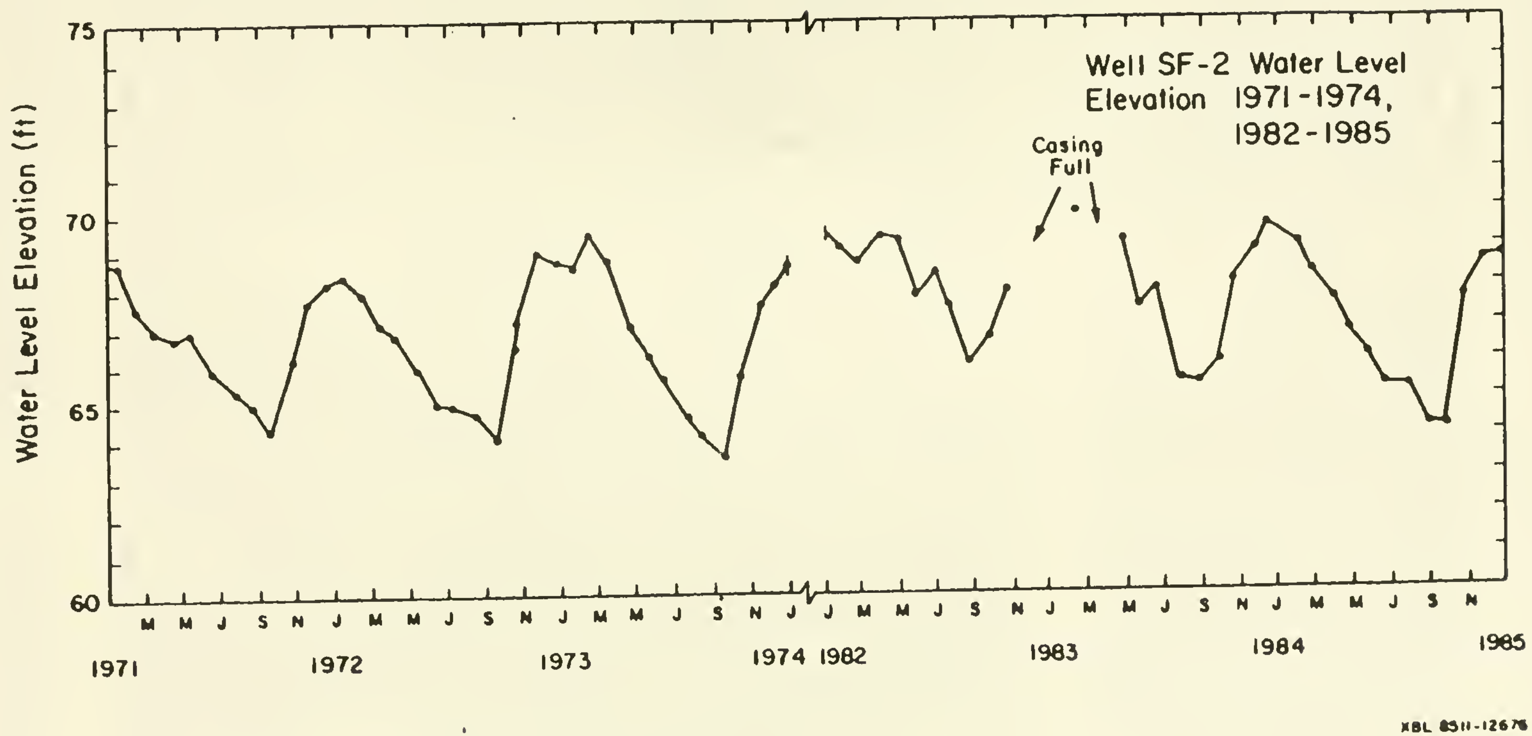

Figure 2. Water table fluctuations measured in Well SF-2

Increases of similar magnitude have been observed in several monitoring wells monitored by Reclamation over the past 20 to 30 years.

Due to the manner in which these lands are flooded and drained, they create a similar impact on the water table each year. The maximum elevation of the diked enclosures creates an upper limit on the water depth, which in turn determines the upper limit of the seepage rate and consequent rise in the water-table elevation. For instance, a greater rate of application or large amount of precipitation will not increase the water-level in the duck ponds because it can not be contained within the diked perimeter of the pond. Unless the duck club operations are altered significantly, i.e., by increasing the depth of the diked ponds or reducing or eliminating intentional flooding, future water-table elevation increases attributable to flooding the duck clubs will be of a similar magnitude to those observed during the current wet season.

Rainfall is another factor that may contribute to increases in the water-table elevation. Approximately 100 years of rainfall data are available from Los Banos and Newman, indicating that the average estimated annual rainfall at Kesterson Reservoir is about 9.5 inches. More than 8 inches typically falls between October and March. When it rains, some fraction of the water infiltrates through the soil profile, increasing the water content of the soil. Although infiltration rates in the majority of the unfilled areas of the Kesterson soils are presently high enough to accommodate even fairly intense rainfall events, their fine texture tends to hold the moisture close to the soil surface, rather than allow it to infiltrate freely to the top of the water-table. In the days and weeks following a rainfall event, since the water is held close to the soil surface, evaporation at the soil surface and evapotranspiration from plants draw some fraction of this water out of the soils. Pan evaporation rates from Kesterson Reservoir average about 2.4 inches per month over the period from November to March and are nearly equal to the monthly rainfall averages. Thus, infiltration alone is not sufficient to create a significant increase in the water-table elevation following an average rainfall event. The above discussion is consistent with the observation that in dry and normal water years, local rainfall does not appear to constitute an important contribution to the rise in water-table elevation. In addition, modeling studies that neglected this component achieved a reasonable match between observed and calculated water-table elevations (Mandle, R. J., and Kontis, A. L., US Geological Survey Water Resources Investigations Report 86-4196, 1986).

In a year with heavy rainfall or following an unusually intense or prolonged rainfall event, the situation may be quite different. Precipitation may exceed evaporation, leaving an

excess of water to pond or infiltrate into the soil. In this event rainwater may infiltrate to the water-table and contribute to seasonal rise. If all the pore space between the water-table and the soil surface becomes saturated, the water-table will in effect have risen above the ground surface. It should be noted that ponding occurring due to this mechanism is significantly different than the type of ponding that has been observed in the past, where the water-table rose above the ground surface due to the hydraulic influence of flooding the surrounding lands. In the event that puddles form from rainfall, the surface water will consist almost entirely of rainwater; whereas, when formed from the hydraulic influence of flooding the duck clubs, pore water displaced from the vadose zone constitutes a significant fraction of the ponded waters. Further discussion of the selenium concentrations expected in these pools is provided in the Final Cleanup Plan report that accompanies this document.

To assess the potential for surface ponding at Kesterson Reservoir during very wet years an estimate was made of the quantity of rain that would be required to fill all of the pore space between the ground surface and the elevations of the water-table at Kesterson Reservoir. To make these estimates the following assumptions were made:

1) The water available for infiltration is equal to rainfall minus potential evaporation (e.g., no perched or ponded water would persist).
2) The porosity of the surface material averages 35 percent.
3) The average water saturation in the region between the water-table and the soil surface is 80 percent in the unvegetated areas and 60 percent in the vegetated areas.
4) Total evaporation from November to March is 9.5 inches.
5) Surface run-off does not occur.
6) Plant uptake from soil moisture is equivalent to 1 inch of water during the period from November to March.
7) The downward flow of water below the water-table is neglible.

Using these assumptions, the amount of rain required to fill the region between the ground surface and the water-table was calculated for various depths to the water-table. Results are summarized in Table 3. Comparison between these values and the average depths to the water-table listed in Table 2 indicates that, for unvegetated soils, rainfall in excess of 13 inches may fully saturate the soils in most parts of the Reservoir. In comparison, over 16 inches would be required to fully saturate most vegetated soils.

Table 3. Estimated Rainfall Amounts To Fully Saturate Kesterson Reservoir Soils

Depth To Water Table (feet)	Vegetated Soils (inches)	Unvegetated Soils (inches)
1.5	13	11
2.0	13.9	11.4
2.5	14.7	11.9
3.0	15.5	12.4
3.5	16.4	12.9
4.0	17.2	13.3
4.5	18.1	13.8

As another approach to evaluate the effect of years of heavy rainfall on water-table elevations, water level records were reviewed to see if years of heavy rainfall correlated with unusually large increases in water-table elevations. Although a straight-forward analysis of this correlation is difficult, during 1969 and 1973, when annual rainfall was about 15 inches, apparent water level increases of up to 2 feet above the normal increases were observed in several shallow monitoring wells. Despite the preliminary and rather simplistic nature of the above-described analyses, it is clear that during unusually heavy rainfall years, at least some of the Reservoir soils could saturate and surface ponding will occur.

<u>Surface Water</u>

In order to evaluate the frequency of occurrence of years in which heavy rainfall may cause surface ponding at Kesterson Reservoir, rainfall records published by DWR were examined. Records are available for Los Banos and Newman for about 100 years. Annual rainfall at Kesterson was estimated by taking the average of the values from Newman and Los Banos because Kesterson is approximately equidistant from the two. This estimate was verified by comparing Kesterson data for the period between 1982 and 1988 with the average of the two values.

Using this approach the probability distribuition for various annual rainfall quantities was calculated and is shown in Table 4.

Table 4. Return Period for Annual Precipitation

Annual Precipitation (Inches)	Cumulative Probability (Percent)	Exceedance Return Period (Years)
10	40	2.5
11	30	3.3
12	22	4.5
13	15	6.7
14	11	9.1
15	8	12.5
16	5	20
17	3.5	29
18	2.2	45
19	1.6	62
20	1.1	91

Years with rainfall totals greater than about 13 inches, which could be expected to cause surface ponding in most unvegetated areas of the Reservoir, would be predicted to occur about once in 7 years. Unvegetated areas in Ponds 3, 4, and 6 could be expected to become saturated about once in 3 years. Years with totals exceeding 16 inches, which could be expected to cause ponding in most vegetated areas of the Reservoir, would be predicted to occur no more than about once in over 20 years.

SUMMARY AND CONCLUSIONS

A contract was issued on July 6, 1988, the day following the adoption of State Board Order No. WQ 88-7; and the contractor was mobilized and began operation within 2 weeks. A total of 1,050,437 cubic yards of material was placed in low lying areas of the Reservoir by November 16, prior to any significant rainfall. The soil surface is now at least 1 foot above the average ground-water elevation in all areas of Kesterson Reservoir. In many areas of the Reservoir the surface is up to several feet above the average ground-water elevation.

Analysis indicates that the primary cause of the seasonal rise in the water-table is the flooding of nearby duck club lands. The effect on the water-table is relatively constant from year to year and there is an upper limit determined by the acreage and depth of the diked duck club ponds. Thus, the water-table rise observed this year represents the maximum extent of water-table rise expected from the hydraulic influence of flooding the surrounding wetlands. Highly seleniferous ephemeral pools formed by rising ground water, as were observed in the past, are not anticipated at Kesterson Reservoir in the future.

Analysis further indicates that, in years with normal and below normal precipitation, local rainfall does not contribute significantly to a rise in the water-table elevation. In years of above normal rainfall, however, precipitation may exceed evaporation and rainfall may infiltrate to the water-table and contribute to seasonal rise. It is predicted that above-normal rainfall years with a return frequency of about 3 years will cause some surface pooling, at least in some areas of the Reservoir.

The pools that may form at Kesterson Reservoir in the future will be significantly different from the pools formed by rising ground water that occurred in the past. Future pooling at the Reservoir will occur by restricted infiltration or by saturation of the soil down to the water-table and surface water will consist almost entirely of rainwater rather than water displaced from the vadose zone. The probability of occurence and the extent of pooling is expected to decrease with time as the open and filled areas become more vegetated.

The objective of filling the ephemeral pools at Kesterson Reservoir was to address the acute problems associated with high levels of selenium found in ephemeral pools formed by rising ground water. The specific criterion was to fill all ephemeral pool areas to six inches above the rising ground water by January 1, 1989. The filling operation has been completely successful in meeting both the objective and the criterion. In addition, in all Ponds except those immediately adjacent to flooded duck clubs, i.e., Ponds 3, 4, and 6, there is a considerable margin of safety in accommodating above normal rainfall.

KESTERSON PROGRAM

UPLAND HABITAT ASSESSMENT

CONTENTS

KESTERSON RESERVOIR
UPLAND HABITAT ASSESSMENT

OBJECTIVE

The objective of the upland habitat assessment is to evaluate the overall quality of Kesterson Reservoir for use by wildlife and to evaluate potential wildlife impacts from post-filling conditions at Kesterson Reservoir. Data that form the basis of this Upland Habitat Assessment have been collected as part of the ongoing Kesterson Reservoir Biological Monitoring Program. Many of the conclusions of this report are preliminary because bird and mammal reproductive seasons for 1989 were not completed at the time this report was prepared, and there is only a limited amount of data available since filling was completed in December 1988. A more complete analysis will be available when the annual Biological Monitoring Report is provided to the Central Valley Regional Water Quality Control Board in December 1989.

HABITAT TRISECTIONS

The drying and filling of Kesterson Reservoir has converted the site to upland habitat, consisting of three habitat types. The first type, grassland habitat, consists of higher elevation areas that were not filled. The grassland habitat is the upland habitat that existed at the reservoir before the reservoir was dried and filled. The dominant vegetation in grassland habitat is saltgrass. The second type, filled habitat, consists of formerly lowlying areas that were filled to prevent the occurrence of seasonal wetlands. The third type, open habitat, consists of former cattail areas that were not filled but were disced to prevent use by tricolored blackbirds.

The acreage of each habitat type in the reservoir was estimated from the January 2, 1989 aerial photograph of the site. The results from these measurements are in Table 1. The grassland habitat covered about 30 percent of the reservoir, approximately 60 percent was filled habitat, and 10 percent was open habitat (Figure 1).

Field data collection in the past has been stratified on the basis of the 12 ponds making up Kesterson Reservoir. Because the ponds will no longer be flooded, and because the levees separating the ponds have been removed as part of the filling operation, monitoring is presently being stratified based on trisections rather than the 12 former pond areas (see Figure 1). The trisections were chosen based on the geographic distribution and operational history of the former ponds.

Trisection 1 consists of the southernmost ponds (Ponds 1, 2, 3, and 4). These ponds are south of Gun Club Road and received large amounts of drainwater in the past. The ponds in this trisection have the highest soil selenium levels. They contained mainly open water and cattail areas in the past and presently contain very little grassland habitat.

Trisection 2 consists of Ponds 5, 6, 7, and 9. These ponds are in the central area of Kesterson (north of Gun Club Road), and also received substantial amounts of drainwater. The ponds in this trisection generally have lower soil selenium levels than the ponds in Trisection 1. They contained open water and cattail areas and also presently contain some grassland habitat.

Trisection 3 consists of the northern ponds (Ponds 8, 10, 11, and 12). These ponds received the least amount of drainwater. The ponds in this trisection have the lowest soil selenium levels and contain large areas of grassland habitat.

Because of construction activity, habitat sampling in the summer of 1988 concentrated on vegetated grassland habitat that was expected to remain unfilled in Trisections 2 and 3. Habitat sampling in the fall of 1988 and winter of 1989 involved collecting samples from all three trisections and all three habitat types. Three sample sites of each of the three habitat types were sampled in each trisection. The sample sites were chosen by USBR and USFWS biologists prior to the sampling periods and were representative of the habitat types found in each trisection.

PLANTS AND INVERTEBRATES

During the summer of 1988, the filling operation was in progress and samples could not be collected from Trisection 1 or any open or filled habitat areas in the other trisections. In the fall of 1988, samples were not collected from open and filled habitats because there were no plants or invertebrates present. Only preliminary results are available from the winter of 1989 sampling.

Selenium levels[1] in dominant vegetation in each habitat type are shown in Tables 2, 3, and 4. All of the plants, with the exception of annual grasses from the filled habitat, showed the general trend of decreasing selenium concentration from south to north. However, differences between trisections were usually not statistically significant. The declining trend from south to north may be related to the

[1]All selenium concentrations presented in this report are on a dry weight basis.

similar trend found in total soil selenium. Any relationship between total soil selenium and plant selenium concentration must be interpreted with caution, however, because a constant fraction of total soil selenium is not necessarily available for plant uptake.

The geometric mean selenium concentration of all aboveground vegetative portions of grassland habitat plants sampled since August 1988 is 2.6 ppm (n = 112, range = 0.1-17.7). Selenium concentrations in belowground portions and seeds are similar. Tables 2, 3, and 4 show selenium concentrations for individual species in each trisection.

Annual grasses were the dominant vegetation occurring in the filled habitat throughout the reservoir during the winter sampling period. The geometric mean selenium concentration in annual grasses collected from the filled habitat was 1.3 ppm (n = 9, range = 0.7-2.9). Based on pre-filling sampling, the soils in these areas have low selenium concentrations. Plants collected from the filled habitat reflect these low selenium levels.

Clover collected from the open habitat had a geometric mean selenium concentration of 12.3 ppm (n = 9, range = 6.1-27). These plants were rapidly covering bare soil in the open habitat during the winter sampling period. The soil in the open habitat consisted of the former organic layer, mineral soil, and cattail straw that had been mixed together by discing. It is expected that this mixture will have relatively high selenium levels because of the elevated selenium levels that occurred in the organic detritus. Plant selenium levels in the open habitat may reflect the higher soil selenium concentrations.

The geometric mean selenium concentration in grassland and filled habitat plants at Kesterson was below or near the formerly adopted cleanup goal of 3 ppm selenium for potential bird and mammal food. Research on what the safe level of selenium is in wildlife food continues.

Selenium levels in invertebrates are summarized in Table 5. Invertebrates were collected by using pitfall traps, aerial sweep nets, and by searching the ground under debris and the vegetative covering. Using these methods, the invertebrates most available to wildlife predators were collected. Invertebrates were collected during the summer of 1988, but few invertebrates were found during the fall 1988 sampling period. (Fall is normally a time of low activity for many invertebrates due to the cold temperatures, frequent rain, and short daylength.) Greater numbers of invertebrates were collected during the winter 1989 sampling period. During this sampling period the days were milder and dryer than during the fall sampling period. The results of the winter sampling period selenium analyses are not yet available.

The overall geometric mean selenium concentration in invertebrates (with the exception of sowbugs) collected from the grassland habitat at Kesterson Reservoir since August 1988 was 8.4 ppm (n = 94, range = 1-51). The geometric mean selenium concentration ranged from 4.3 ppm (n = 24, range = 1.9-8.3) in grasshoppers to 11.9 ppm (n = 13, range = 1-21) and 9.3 ppm (n = 17, range = 3-31) in crickets and beetles, respectively.

The overall geometric mean selenium concentration in sowbugs was 56.6 ppm (n = 29, range = 23-210). These high selenium levels in sowbugs are apparently related to the similarly high selenium levels in soil litter (Table 6) where sowbugs live and forage. The soil litter consists of organic and inorganic sediments mixed with dead and decaying plant material. Some of these materials may remain from when these grassland habitats were occasionally flooded with drainwater in the past. Sowbugs have not been found in the digestive tracts of birds and mammals examined to date.

It should be noted that crickets, beetles, and other organisms employ a variety of feeding strategies that can include both vegetation and soil litter. This may account for the wide range of selenium concentrations found in crickets and beetles and the generally higher selenium level found in these organisms than found in grasshoppers, which feed primarily on living vegetation. Predatory invertebrates, such as spiders, will have selenium concentrations that reflect the ranges observed in their prey, which includes most of the invertebrates found at Kesterson. The importance of the litter based food chain is unknown but monitoring of soil litter and organisms that utilize it is continuing.

BIRDS

BIRD USE

Most duck, coot, and shorebird, (except for kildeer and snowy plover) habitat for both foraging and nesting has been eliminated at Kesterson Reservoir. These species (except for killdeer and snowy plover) are not expected to forage at Kesterson in the future, although some nesting could potentially occur there.

Killdeer nest along levee roads and are associated with grassland habitat. Killdeer are expected to continue to use the Reservoir. Snowy plovers nest in flat areas of mud or sand and may continue to nest and feed in the Reservoir.

Terrestrial species of birds such as western meadowlarks, horned larks, white-crowned sparrows, mourning doves, barn swallows, nighthawks, ring-necked pheasants, and red-tailed

hawks have been observed at Kesterson in the past but their use was not quantified. Censuses are now being conducted to quantify use by these species, document use patterns, and help determine any effects of selenium on birds using Kesterson Reservoir. The results of censusing completed to date are summarized in Table 7.

No dead birds have been observed at Kesterson Reservoir since a dead coot was salvaged on July 1, 1988.

TRICOLORED BLACKBIRDS

DeHaven et al. (1975) found tricolored blackbirds to roost and nest primarily in cattail, bulrush, and blackberry. Cattails and other emergent vegetation have been eliminated from Kesterson Reservoir and are not expected to occur in the future because the reservoir will be managed to prevent regrowth. The lack of suitable habitat for roosting and nesting of tricolored blackbirds inside Kesterson Reservoir should prevent tricolored blackbirds from using Kesterson in the future. Because tricolored blackbirds are expected to roost and nest nearby on the Kesterson National Wildlife Refuge, some use of the site for foraging may occur. If tricolored blackbirds are observed foraging on the reservoir, attempts will be made to identify the nesting or roosting area and inform the USFWS.

BIRD NESTING

During 1988, the eggs and nests of two bird species that used grassland habitat were monitored routinely: barn swallows and killdeer. Also, nests of western meadowlarks and mourning doves were monitored when found.

Nests were actively searched for 2 or more days a week. Twenty-eight barn swallow nests, 15 killdeer nests, 5 western meadowlark nests, and 1 mourning dove nest were discovered. For barn swallows and killdeer, the number of monitored nests was a large fraction of the total number of nests present. Nests of western meadowlarks and other upland species were not actively searched for, so more nests than those examined were probably present. Nest surveys in future biological monitoring will include, but not be limited to, meadowlarks, killdeer, lesser nighthawks, northern harriers, barn swallows, and ring-necked pheasants. Barn swallow numbers will be reduced at Kesterson in the future because most of the culverts used for nest sites have been eliminated as part of the filling operation.

Twenty-four eggs were collected out of 15 killdeer nests; all were fertile but one. The geometric mean selenium concentration in eggs was 15.0 ppm (range = 6.5-58). This selenium concentration is in the range that has been associated with embryotoxicity for other species in the presence

of drainwater. One killdeer embryo, when observed under the microscope, had an unusually elongated torso. The selenium concentration in this embryo was elevated (40 ppm) but the abnormality was not one previously associated with selenium toxicity, or one that was obvious to the untrained eye. No other abnormalities or mortalities were observed in killdeer.

Barn swallows had a high degree of breeding success. Twenty nests were monitored through the nesting stage with no observed mortality. One egg collected from a nest after the sampling period had ended (no new barn swallow nests were starting) contained a dead embryo with a selenium concentration of 6.4 ppm. In many species the older, more experienced birds breed earlier than those breeding for the first time. Younger, less experienced birds in some species have been found to be less successful (Perrins and Birkhead 1983). This may explain the dead embryo in this late nest. A total of 33 barn swallow eggs were collected with a geometric mean selenium concentration of 6.7 ppm (range = 3.8-11). No abnormalities or other mortalities were observed in barn swallows.

Western meadowlarks were observed and their eggs collected opportunistically. Five nests were found in 1988. Three nests had normal nestlings in them when they were discovered. The nests were inspected and no unhatched eggs or dead nestlings were found. Two of the nests contained eggs, one egg was collected from each of these nests. Their selenium concentrations were 24 ppm and 22 ppm, respectively. No mortality or abnormalities were observed in 1988 although the small sample size makes generalizing to the entire western meadowlark population at Kesterson impossible. Sample size during 1989 is being increased to allow a more complete analysis to be made.

The geometric mean selenium concentration in killdeer and meadowlark eggs was higher than that expected to be found in uncontaminated areas and was at a level associated with embryonic mortality and deformity in the presence of drainwater (Ohlendorf et al. 1986). However, no selenium-related embryotoxicity was found in the few nests of terrestrial bird species at Kesterson during the 1988 nesting season. Although levels of selenium in eggs of upland species were elevated, the data must be interpreted with caution. Extrapolating embryotoxicity between species under different environmental conditions is not appropriate. The observations in killdeer at Kesterson Reservoir this year do not seem to support the prediction of embryotoxicity based on the concentration of selenium found in the eggs of other species and in the presence of drainwater. This lack of embryotoxicity may be due to changes in the matrix of contaminants at Kesterson since drainwater delivery was discontinued, species-specific responses to selenium, or other

changes in environmental conditions at Kesterson Reservoir. Continuing monitoring will attempt to identify any selenium related bird embryotoxicity or fledgling mortality that may occur.

BIRD FOOD HABITS AND LIVER SELENIUM

As part of adult upland bird surveys, red-winged blackbirds and western meadowlarks were collected. Four western meadowlarks were also collected from the Volta Wildlife Area.

Red-winged blackbirds are primarily seed eating birds that can be found foraging singly, in pairs, or in flocks. In spring and summer 40 to 50 percent of their food may be animal food consisting of beetles, caterpillars, grubs, grasshoppers, ants, and occasionally snails, spiders, and crustaceans (Martin et al. 1951).

Red-winged blackbirds collected from Kesterson in the spring of 1988 contained a variety of seeds and aquatic invertebrates. The blackbirds collected had been observed feeding on aquatic invertebrates in muddy areas exposed by dewatering. The geometric mean for selenium in the livers of these 16 birds was 24.5 ppm (range = 14.5-40). Red-winged blackbirds were collected mainly as surrogates for the tricolored blackbird. Although neither species are expected to nest at Kesterson Reservoir in the future, they may occasionally feed at this site.

Western meadowlarks are primarily insectivorous birds that forage singly or in small groups by pecking and probing in the soil litter. Their diet consists mainly of beetles, crickets, grasshoppers, caterpillars, ants, bees, wasps, and bugs. In the winter, over 50 percent of their diet may consist of plant foods (Martin et al. 1951; Knowlton and Maddock 1943).

Western meadowlarks were collected in Kesterson Reservoir and Volta Wildlife Area. The food items in the meadowlark digestive tracts from the spring collection at Kesterson included beetles, crickets, and some aquatic invertebrates. The geometric mean for liver selenium in these birds was 30.3 ppm (n = 10, range = 15-76). This level may be high enough to cause reproductive problems, although none were observed in the few western meadowlark nests monitored in 1988. In August at Kesterson, meadowlark digestive tracts contained mostly grasshoppers, and the geometric mean liver selenium concentration in these birds was 10.1 ppm (n = 4, range = 8.4-12). For meadowlarks collected from Volta in June, grasshoppers were the most abundant food item. The geometric mean selenium concentration in the livers of the Volta birds was 4.1 ppm (n = 5, range = 3.3-4.7). It is unknown whether the lower liver selenium concentrations in

the summer represent part of a seasonal cycle or changes in the food habits of the birds. The birds collected during the summer also may have been recent immigrants to Kesterson.

The soil litter and sowbug food chain is an area of concern because of their elevated selenium levels. Some meadowlark food items are found in the soil litter and some litter may be ingested along with food items. Sowbugs are a possible source of selenium in western meadowlark food, but they were not observed in any of the 19 meadowlarks examined from Kesterson Reservoir and Volta WMA in 1988. It is not known whether this is typical, if sowbugs are not palatable to the birds collected, or if they are for some reason unavailable. Two hundred eighty-four stomach samples from horned larks, sage sparrows, and western meadowlarks were examined by Rotenberry (1980) without finding sowbugs. In 1943, Knowlton and Maddock examined 172 western meadowlark stomach contents and found only one sowbug. Bent (1965), however, mentions sowbugs as a possible minor food item.

The selenium concentrations found in meadowlark livers were elevated compared to all species of birds collected from Volta Wildlife Area during 1983-1985. In addition, these selenium concentrations in meadowlarks were similar to levels in various species of ducks (1983 and 1984), avocets (1984), and killdeer (1984), sampled at Kesterson. Ducks exhibited reproductive problems at Kesterson during that period. No reproductive problems, however, were observed in the five meadowlark nests at Kesterson Reservoir in 1988. Monitoring of bird food habits and liver selenium will continue.

MAMMALS

Selenium levels in small mammals at Kesterson Reservoir were generally highest in the southern ponds and lowest in the northern ponds (Table 8). This trend in concentration may be related to a similar trend found in upland plants and invertebrates.

Selenium levels found in small mammals in 1988 were similar to those found in 1984 (Clark 1987). During 1984, no adverse reproductive or growth impact to small mammals resulting from selenium was observed at Kesterson. High selenium concentrations in small mammals, however, may threaten predatory reptiles, birds, and mammals (such as the endangered San Joaquin kit fox) that feed on them.

Selenium levels in the deer mice analyzed in 1989 were lower than those concentrations observed in 1988 and were similar to those observed in 1987. Selenium concentrations in small mammals collected in 1987, 1988, and 1989 are summarized in

Table 8. Traps were set for deer mice in all three habitat types. Trapping success in early 1989 for deer mice was highest in filled habitat adjacent to grassland habitat. The high trap success in these areas and the decreased selenium concentrations in deer mice from 1988 to 1989 may be explained by the tendency of deer mice to increase their utilization of areas that have been disturbed by cutting. Deer mice show a positive response to sparse vegetative covering (LoBue and Darnell, 1959) such as that in the filled habitat in 1989 and the areas exposed by dewatering in 1988.

In 1988, deer mice moved into areas of Kesterson Reservoir where dewatering had exposed food items with elevated selenium concentrations. In 1989, the disturbed areas used by the deer mice were the filled habitat areas. Selenium concentrations in food items were low in these areas and the selenium levels in deer mice reflected the levels in their diet.

Three deer mice collected from each trisection for selenium analysis had their stomach contents removed and examined. This preliminary sample shows no obvious relationship between specific food items and selenium concentrations in deer mice. No sow bugs were found in any of the stomachs examined.

The impact of the high selenium concentrations in clover to wildlife using the open habitat areas is not yet apparent. There appeared to be very little wildlife activity in the open areas; scat, footprints, signs of foraging on clover, and other signs of utilization were not observed. Voles appeared to be most active in open areas, but forage primarily on stems and roots. Stomach contents from individuals collected from the open areas will be used to determine if the voles are foraging on material disced into the soil or new growth.

The results of a recently completed kit fox study (Paveglio and Clifton 1988) showed that, because of the minimum use of Kesterson by the small population of the endangered San Joaquin kit fox in the Kesterson area, it is unlikely that the elevated levels of selenium in the small mammal prey base at Kesterson have had a negative effect on kit foxes. In this same study, two of eleven coyotes collected from Kesterson Reservoir contained liver selenium levels within the range associated with chronic selenium toxicosis in domestic dogs. One possible cause for the high levels of selenium in the coyotes collected from the Kesterson area may have been due to the high utilization of American coots in their diet. Over 28 percent of the volume in stomachs from these coyotes was made up of American coot remains. Coots were part of the aquatic food chain eliminated from Kesterson by the filling operation. Unlike the coyotes, San

Joaquin kit fox scats examined contained no trace of coot remains or other components of the aquatic food chain. One of these two coyotes contained clinical signs associated with selenium toxicosis. However, because of severe post-mortem tissues autolysis, a final diagnosis for this animal could not be made. Because of these observations, monitoring of kit fox use will continue.

A study of raccoons at Kesterson in 1986 also showed elevated levels of selenium (Clark et al. in press). As with small mammals, however, there was no evidence that contamination had adverse effects on raccoons inhabiting Kesterson.

NIGHT SURVEYS

Beginning in January 1989, night surveys were conducted bimonthly at Kesterson Reservoir and adjacent areas. The surveys indicated the greatest small mammal use in the filled and grassland habitats. Black-tailed hares and striped skunks were most frequently observed in filled areas. Cottontails were most often seen in grassland habitat. Coyotes were observed in all habitat types throughout the Kesterson Reservoir. Foxes have not been observed in Kesterson Reservoir or in adjacent areas in night surveys conducted since January although they have been documented to use Kesterson Reservoir and vicinity (Paveglio and Clifton, 1988).

RAINWATER PUDDLES

As anticipated, numerous shallow rainwater puddles formed on top of filled habitat after rainfall events. These puddles formed where there were slight topographic depressions and/ or where soils were heavily compacted by equipment during the filling operation. Following rainfall events it was estimated that puddles covered up to about 1 percent of the filled habitat. No significant puddling was observed in either the open or grassland habitats at the Reservoir. Within a matter of a few days following the rainfall event many of the surface puddles had disappeared. However, in some areas puddles persisted for weeks, usually overlapping subsequent rainfall events. The largest of these persistent puddles was located in trisection 1 and varied between about 1/3 and 1/4 acre in size. In total, these persistent puddles encompassed a total of about 3 acres, or about 1/4 percent of the entire Kesterson Reservoir Area.

Reservoir-wide, the geometric mean selenium concentrations in rain puddles was 4.0 ppb (n = 53, range = <1-50). A general trend of decreasing selenium concentration from south to north was observed (Table 9). This trend is similar to trends observed in total soil samples and vegetation. The highest concentrations were found in puddles in Trisection 1.

Large, persistent puddles were checked weekly for aquatic plants and invertebrates and signs of wildlife use. No signs of wildlife use, aquatic plant, or invertebrate life were found in trisections 2 or 3 puddles. In late February, aquatic invertebrates were discovered in a group of puddles in Trisection 1. These puddles also had widgeongrass seeds and signs of wildlife activity around their edges. Seeds, aquatic beetles, and a few water boatmen were collected for selenium analysis, but these analyses are not yet complete.

SUMMARY

This report presents an assessment of wildlife impacts resulting from the post-filling upland habitat at Kesterson Reservoir. Many of the conclusions of this report are preliminary because bird and mammal reproductive seasons for 1989 were not completed at the time this report was prepared and there is only a limited amount of data available since filling was completed in December 1988. A more complete analysis will be available when the annual biological monitoring report is submitted to the Central Valley Regional Water Quality Control Board in December 1989.

The drying and filling of Kesterson Reservoir has converted the site to upland habitat consisting of grassland, filled, and open habitats. Selenium levels in vegetation from grassland and filled habitat are near or below the formerly adopted cleanup goal of 3 ppm in wildlife food. Selenium levels in vegetation from the open habitat are higher, probably reflecting the elevated soil selenium levels in that habitat type.

Selenium levels in invertebrates reflect the selenium concentration in their diet. Selenium levels range from near 3 ppm in grasshoppers to over 50 ppm in sowbugs. The high selenium levels in sowbugs are apparently related to the similarly high selenium levels in soil litter where sowbugs live and forage. The importance of the litter based food chain is unknown although sowbugs have not been observed in the digestive tracts of birds and mammals examined to date.

Since the completion of filling, bird species using Kesterson have changed from mainly aquatic species to terrestrial species. Prior to filling the types of birds using Kesterson included ducks, coots, and shorebirds. Filling reduced use of Kesterson by most of these species. Terrestrial species such as western meadowlarks, horned larks, white-crowned sparrows, mourning doves, barn swallows, ring-necked pheasants, northern harriers, and red-tailed hawks are presently using the Reservoir.

No dead birds have been observed at Kesterson Reservoir since July 1, 1988.

Because of its status as a candidate species for listing under the Endangered Species Act, the tricolored blackbird has been a species of concern at Kesterson in the past. Tricolored blackbirds are expected to neither roost nor nest in Kesterson Reservoir in the future because all cattail habitat has been eliminated and will be prevented from reoccurring.

Among other terrestrial bird species, 27 barn swallow nests, 15 killdeer nests, 5 western meadowlark nests, and 1 mourning dove nests were discovered at Kesterson in 1988. The mean selenium concentrations in killdeer and meadowlark eggs were higher than that expected to be found in uncontaminated areas and was at a level associated with embryonic mortality and deformity at Kesterson in the past in the presence of drainwater. However, no selenium-related embryotoxicity was found in terrestrial bird species at Kesterson during the 1988 nesting season. This lack of embryotoxicity may be due to changes in the matrix of contaminants at Kesterson since drainwater delivery was discontinued, other changes in environmental conditions at Kesterson Reservoir, or species specific selenium embryotoxicity relationships.

Adult western meadowlarks were collected in Kesterson Reservoir and Volta Wildlife Area. The selenium level in the livers of birds collected from Kesterson was elevated. This level may be high enough to cause reproductive problems, although none were observed in the few western meadowlarks observed in 1988.

Selenium levels found in small mammals in 1988 were similar to those found in 1984. During 1984, although selenium levels were elevated above those found in control areas, no adverse reproductive impact resulting from selenium was observed in small mammals at Kesterson. Selenium levels in deer mice collected in 1989 were lower than concentrations observed in deer mice collected in 1988.

High selenium concentrations in small mammals may threaten predatory birds and mammals, such as the endangered San Joaquin kit fox, that feed on them. The results of a recently completed kit fox study by the Fish and Wildlife Service showed that a small population of San Joaquin kit fox rarely used Kesterson Reservoir in 1987 and 1988. Therefore, it is unlikely that the elevated levels of selenium in the small mammal prey base at Kesterson have had a negative effect on kit foxes.

A study of raccoons at Kesterson in 1986 also showed elevated levels of selenium. As with small mammals, however, there was no evidence that contamination had adverse effects on raccoons inhabiting Kesterson.

Based on the most recently completed sampling some plants, invertebrates, birds, and mammals continue to have elevated selenium levels. However, no adverse impact to wildlife has been observed since the completion of filling, although the time since filling has been completed is too short to make a definitive assessment. Monitoring is continuing to document changes in selenium levels and any wildlife impacts that may occur.

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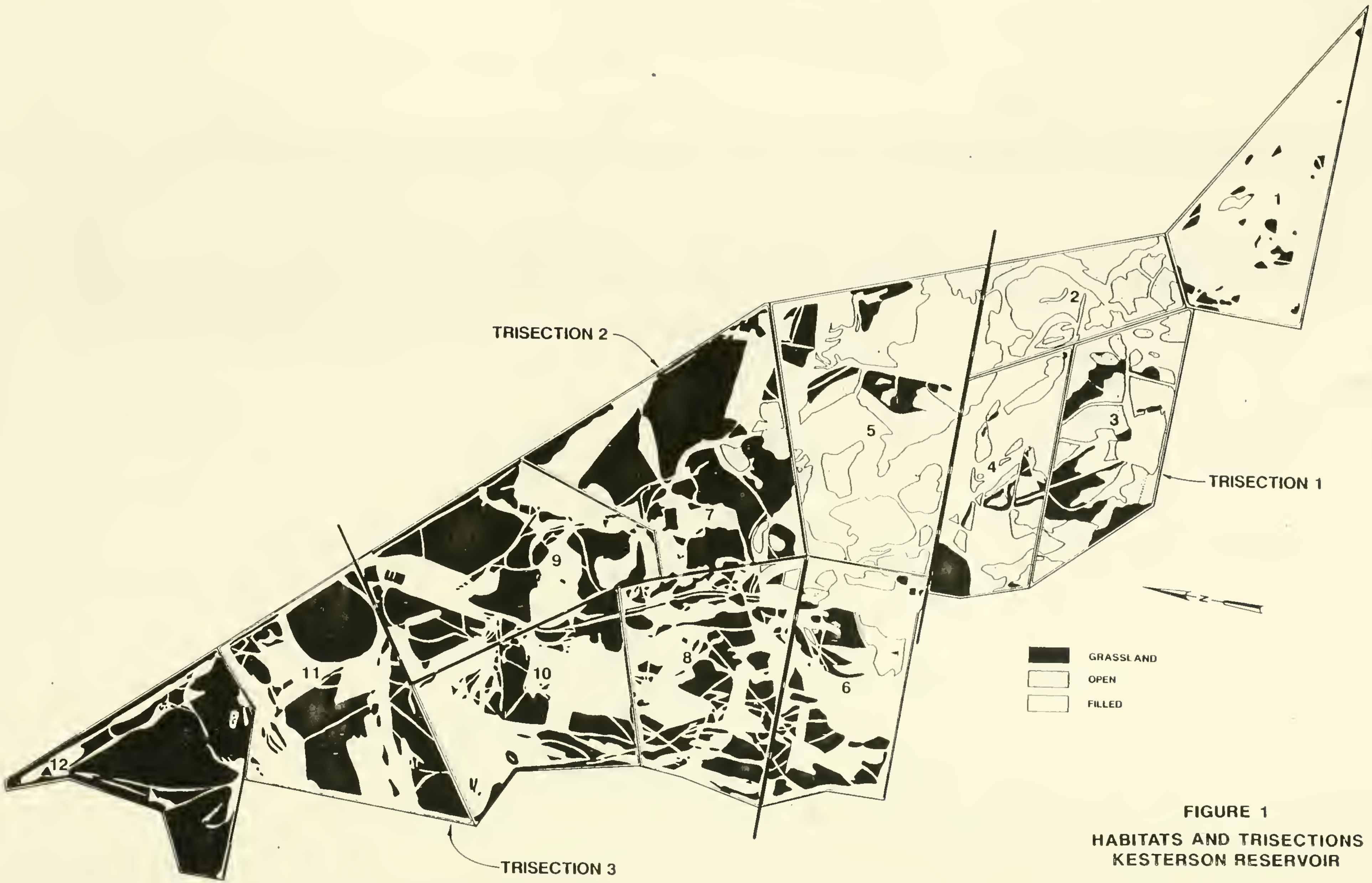

FIGURE 1
HABITATS AND TRISECTIONS
KESTERSON RESERVOIR

Table 1

Kesterson Reservoir
Habitat Breakdown of Kesterson Reservoir
(Acres)

Habitat	Trisection 1					Trisection 2					Trisection 3				
	Pond 1	Pond 2	Pond 3	Pond 4	Total	Pond 5	Pond 6	Pond 7	Pond 9	Total	Pond 8	Pond 10	Pond 11	Pond 12	Total
Grassland	6	1	17	7	31	16	21	80	62	178	38	33	59	57	187
Filled	90	24	33	53	199	89	63	57	67	275	76	68	68	27	239
Open	1	38	32	18	89	61	10	8	0	79	1	0	0	0	1
Total Acres	97	62	82	78	319	165	94	145	128	532	114	101	127	84	427

Acreages are approximate.

Measurements of habitat type were taken from an aerial photograph taken in January 1989.

Table 2

Kesterson Reservoir
Above Ground Plant Selenium Concentrations
(ppm dry weight)

Sample Type: Salt grass (Grassland); Alkali Heath (Grassland); Burning bush (Grassland)

	Salt grass Trisection 1	Salt grass Trisection 2	Salt grass Trisection 3	Alkali Heath Trisection 1	Alkali Heath Trisection 2	Alkali Heath Trisection 3	Burning bush Trisection 1	Burning bush Trisection 2	Burning bush Trisection 3
Summer 1988									
N		12	12		12	12		11	11
Range		0.86-4.2	0.5-2.6		1.7-17.7	0.1-14.9		0.2-3.7	0.52-3
Geometric Mean		2.0	1.3		5.1	3.2		1.3	1.1
Fall 1988									
N	3	3	3	3	3	3			
Range	2.7-6.8	1.6-3.6	0.8-2.7	2.3-7	2.1-6.8	1.3-8.2			
Geometric Mean	5.0	2.5	1.8	4.8	3.7	3.0			
Winter 1989									
N									
Range									
Geometric Mean									

Sample Type: Alkali weed (Grassland); Clover (Open); Annual grasses (Filled)

	Alkali weed Trisection 1	Alkali weed Trisection 2	Alkali weed Trisection 3	Clover Trisection 1	Clover Trisection 2	Clover Trisection 3	Annual grasses Trisection 1	Annual grasses Trisection 2	Annual grasses Trisection 3
Summer 1988									
N		12	12						
Range		2.5-9.4	1.9-10.8						
Geometric Mean		5.6	4.3						
Fall 1988									
N									
Range									
Geometric Mean									
Winter 1989									
N				3	3	3	3	3	3
Range				11-27	11-15	6.1-18.7	1.2-1.7	0.7-2.0	0.7-2.9
Geometric Mean				15.3	12.9	9.5	1.4	1.0	1.5

Table 3

Kesterson Reservoir
Below Ground Plant Selenium Concentrations
(ppm dry weight)

Sample Type: Salt grass (Grassland) | Alkali Heath (Grassland) | Burning bush (Grassland)

	Salt grass Trisection 1	Salt grass Trisection 2	Salt grass Trisection 3	Alkali Heath Trisection 1	Alkali Heath Trisection 2	Alkali Heath Trisection 3	Burning bush Trisection 1	Burning bush Trisection 2	Burning bush Trisection 3
Summer 1988									
N		12.	12.		12	12		11	11
Range		0.5-12.5	0.64-5.3		3.2-39.4	1.2-28.7		1.1-6.2	0.2-2.9
Geometric Mean		3.8	1.7		7.6	4.6		2.1	0.8

Sample Type: Alkali weed (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		12	12
Range		2-12.2	2.5-13.5
Geometric Mean		5.8	5.6

Table 4

Kesterson Reservoir
Plant Séed Selenium Concentrations
(ppm dry weight)

Sample Type: Salt grass (Grassland) | Alkali weed (Grassland)

	Salt grass (Grassland)			Alkali weed (Grassland)		
	Trisection 1	Trisection 2	Trisection 3	Trisection 1	Trisection 2	Trisection 3
Summer 1988						
N		10	12		9	10
Range		0.62-6.5	0.4-15		0.8-4.1	0.6-4.9
Geometric Mean		1.8	1.4		1.8	1.8

Table 5

Kesterson Reservoir
Invertebrate Selenium Concentrations
(ppm dry weight)

Sample Type: Crickets (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		6	6
Range		2.9-27	3-10
Geometric Mean		9.8	6.1
Fall 1988			
N	3	2	2
Range	7.3-12	19-21	1-1
Geometric Mean	9.9	20	1

Sowbugs (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		11	12
Range		47-100	23-210
Geometric Mean		69.6	48.2
Fall 1988			
N	3	3	
Range	59-86	23-56	
Geometric Mean	72.8	39	

Spiders (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		12	13
Range		11-51	5.6-34
Geometric Mean		19.3	12.5
Fall 1988			
N		3	
Range		10-20	
Geometric Mean		13.8	

Sample Type: Bugs (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N			
Range			
Geometric Mean			
Fall 1988			
N		3	
Range		3.3-10	
Geometric Mean		6.7	

Millipedes (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N			
Range			
Geometric Mean			
Fall 1988			
N			3
Range			5.0-37
Geometric Mean			11.7

Beetles (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		8	9
Range		7.2-31	5-16
Geometric Mean		10.2	8.6
Fall 1988			
N			
Range			
Geometric Mean			

Sample Type: Grasshoppers (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Summer 1988			
N		12	12
Range		2.8-7.8	1.9-8.3
Geometric Mean		4.9	3.7
Fall 1988			
N			
Range			
Geometric Mean			

Table 6

Kesterson Reservoir
Soil Litter Selenium Concentrations
(ppm dry weight)

Sample Type: Soil Litter (Grassland)

	Trisection 1	Trisection 2	Trisection 3
Smmer 1988			
N		12	12
Range		22-170	8-120
Geometric Mean		83	48
Fall 1988			
N	3	3	3
Range	57-76	11.4-85	20-34
Geometric Mean	64	31.7	25

Table 7

Kesterson Reservoir
Daily Bird Use

SPECIES/GROUP	1987	1988	1989[a]
DUCKS	202	238	0
COOTS	1,967	2,723	1
SHOREBIRDS	241	611	1
AMERICAN AVOCETS		135	0
BLACK-NECKED STILTS		73	0
KILLDEER		82	4
TRICOLORED BLACKBIRDS (NESTING ONLY)	10,000	0	--
WESTERN MEADOWLARKS	--	--	511[b]
SPARROWS	--	--	2,829[b]
HORNED LARKS	--	--	2,427[b]
WATER PIPPITS	--	--	21[b]
RAPTORS	--	--	11

Note: 1987 and 1988 data is from the month with the highest daily average.
1989 data is from the most current month.

[a] February

[b] From bird census; estimate of the number of individuals on the entire reservoir extrapolated from the total transect counts.

Table 8

Kesterson Reservoir
Deer Mouse Selenium Concentrations
(ppm dry weight)

Sample Type	Deer Mice -- Whole Bodies--			California Voles -- Whole Bodies--			Western Harvest Mice -- Whole Bodies--		
	Trisection 1	Trisection 2	Trisection 3	Trisection 1	Trisection 2	Trisection 3	Trisection 1	Trisection 2	Trisection 3
1987									
N	12	12	12	12				12	12
Range	3.1-22.	2.2-34.	1.-18.	14.-64				2.2-13.	0.6-10.
Geometric Mean	10.3	6.6	2.7	32.3				4.9	3.4
1988									
N	12	12	12	6	3		6	9	12
Range	4.-97.	2.6-79.	1.5-38.	3.2-14.	5.-14.7		8.-38.	2.7-7.5	1.5-6.1
Geometric Mean	26.7	10.3	4.1	8.5	7.4		14.4	4.2	3.9
1989									
N	3	3	3						
Range	2.7-10.6	1.6-5.1	2.9-3.2						
Geometric Mean	6.0	2.8	3.1						

Table 9

Kesterson Reservoir
Rainwater Puddle Selenium Concentrations
(ppb)

Sample Type: Rainwater Puddles (Filled)

	Trisection 1	Trisection 2	Trisection 3
Fall 1988			
N	12	22	19
Range	1-50	<1-32	<1-12
Geometric Mean	12.8	4.7	1.6

KESTERSON RESERVOIR

FINAL CLEANUP PLAN

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KESTERSON RESERVOIR
FINAL CLEANUP PLAN

INTRODUCTION AND PURPOSE

The purpose of this document is to present the Department of the Interior (Department) Final Cleanup Plan for Kesterson Reservoir as specified in the California State Water Resources Control Board Order No. WQ 88-7. This document describes cleanup actions taken to date; current conditions at Kesterson Reservoir; anticipated future conditions at the Reservoir; the Department's plan for further cleanup and related management actions; the relationship of the Department's Plan to the requirements of Subchapter 15, Chapter 3 of Title 23 of the California Code of Regulations (Subchapter 15) referenced in the Board's Order No. WQ 88-7; and a discussion of cleanup goals.

ACTIONS COMPLETED

The Department has completed two major actions with respect to cleanup of Kesterson Reservoir. These are: termination of subsurface agricultural drainage water flow into Kesterson Reservoir; and filling of potential ephemeral pool areas in the Reservoir with soil.

Termination of Subsurface Agricultural Drainage Water Flow

The source of contamination at Kesterson Reservoir was irrigated agricultural drainage water carried to the Reservoir via the San Luis Drain (SLD). On April 3, 1985 the Department entered into an agreement with Westlands Water District to curtail drainwater discharges to the SLD. Drainwater discharge to the SLD was discontinued entirely by June 30, 1986. Since August 1986, when drainwater remaining in the SLD ceased flowing into the Reservoir, no drainwater has been discharged to Kesterson Reservoir. Termination of drainwater flow was a major action that eliminated delivery of contaminants to Kesterson Reservoir. Due to the natural geochemistry of the ground water aquifer beneath Kesterson Reservoir, termination of drainwater discharge to Kesterson Reservoir essentially eliminated the threat of further selenium contamination of the ground water aquifer.

Filling of Kesterson Reservoir Ephemeral Pools

Monitoring and research conducted at Kesterson Reservoir to date have demonstrated that residual contamination at Kesterson Reservoir has manifested itself in significant wildlife impacts

primarily through the aquatic food chain. In order to eliminate this exposure pathway, the Bureau of Reclamation (Reclamation) ceased its flooding of the Reservoir ponds and filled low-lying areas of the Reservoir with 1,050,437 cubic yards of material in 1988. These actions have essentially eliminated aquatic habitat at the Reservoir and, thus, broken the food chain through which wildlife impacts were manifested in the past.

CURRENT CONDITIONS AT KESTERSON RESERVOIR

This section describes the current conditions at Kesterson Reservoir with respect to ground water, surface water, and biota. Information is based on and summarizes data presented in previous research and monitoring reports as well as data presented in the accompanying reports (Effectiveness of Filling Ephemeral Pools at Kesterson Reservoir and Kesterson Program Upland Habitat Assessment).

Ground Water

Reclamation currently samples 28 shallow water quality monitoring wells at Kesterson Reservoir and 47 pollutant plume monitoring wells, on a quarterly basis, as specified in the Central Valley Regional Water Quality Control Board's Monitoring and Reporting Program No. 87-149. This monitoring program was developed in collaboration with the Regional Board to detect and monitor migration of selenium and other constituents under and downgradient of Kesterson Reservoir. Results from this monitoring program have confirmed that the extent of selenium migration into the aquifer has been minimal and that the several small plumes of seleniferous drainwater detected between 1984 and 1986 have now all but disappeared.

At present, only five wells exceed the designated "plume detection level" of 10 ppb selenium, compared to about 30 wells in the period from 1984-1986. Selenium concentrations in these five wells range from 11 to 29 ppb. The rapid decline in selenium concentrations detected after application of drainage water ceased in 1986 is consistent with the well-established research findings that naturally occurring geochemical/microbial processes transform and immobilize soluble selenium in the shallow aquifer underlying the Kesterson Reservoir area.

The drainage water discharged into Kesterson Reservoir also contained elevated levels of salts and boron. Unlike selenium, these constituents moved freely into the aquifer and remain mobile in this environment. The residual plume extends from several feet to about 140-feet below the ground surface with an estimated average depth of about 60-feet. Ground water samples from water quality monitoring wells adjacent to the northeast border of the Reservoir indicate that this plume is confined to a band that extends no more than 1000 feet from the Reservoir in

this direction. Water quality samples to the east of the Reservoir, adjacent to Kesterson Ponds 1, 2 and 5, are limited; however, geophysical measurements of soil conductivity have indicated that the plume of high total dissolved solids (TDS) does not extend more than 1,200 feet from the edge of the Reservoir in the easterly direction.

Surface Water

Ephemeral pools formed by rising ground water did not occur at Kesterson Reservoir during 1988-89. Rainwater puddles were observed to form, however, on the fill material following rainfall events. At their maximum extent, these puddles were estimated to cover up to about one percent of the Reservoir area. Most of the puddles were short-lived and disappeared within days after rain events ceased. Some puddles were more persistent, overlapping rainfall events such that they were present for the entire winter season. The largest of these persistent puddles varied between about 1/4 and 1/3 acre in size and in total the persistent puddles covered about 3 acres or about 1/4 percent of the Reservoir area.

Selenium concentration in surface puddles formed by rainwater had a geometric mean of 4.0 ppb (n = 53, range = <1.0-50 ppb). The selenium observed in the puddles is attributed primarily to seleniferous Kesterson soils being mixed with the fill dirt during the filling operation. Other possible sources of selenium, although likely insignificant, are selenium transported to the surface by capillary action where fill depths were shallow, small concentrations of selenium naturally present in the fill material, and perhaps surface deposition of dust during the filling operation.

Plants and invertebrates that could become available as wildlife food do not have an opportunity to become established in the short-lived puddles. In the more persistent puddles, however, sprouting Ruppia (an aquatic plant) and water beetles were observed in late February and samples were collected. Analysis of the samples for selenium has not yet been completed. Minimal overall use of the puddles by birds was observed.

Biota

Three major habitat types presently exist at Kesterson Reservoir: filled areas covering about 710 acres; grassland areas covering about 400 acres; and open (disced former cattail) areas covering about 170 acres.

A small fraction of the filled areas is covered with the rain puddles described above. The remaining filled area is sparsely covered with recently sprouted annual grasses. Preliminary

analysis of these grasses show a geometric mean selenium concentration of 1.3 ppm (n = 9, range = 0.7-2.9).

The grassland areas are dominated by saltgrass and have been extensively sampled in the past. Sampling of plants and invertebrates has indicated that selenium levels are in general relatively low compared to selenium levels found in the aquatic habitats which formerly existed at the site. The geometric mean selenium concentration in all upland plants sampled since August, 1988, is 2.7 ppm (n = 112 range = 0.1-17.7). The geometric mean selenium concentration in all invertebrates, excluding sowbugs, sampled since August, 1988, is 8.4 ppm (n = 94, range = 1-51). Much higher selenium levels (geometric mean = 59.5 ppm, n = 23, range = 23-210) have been measured in sow bugs. These levels are apparently related to similarly high selenium levels in soil litter where sow bugs live and forage. High selenium levels in the soil litter are attributed to deposition of sediments and vegetation in the past when grassland areas were occasionally flooded with drainwater. The importance of the litter-sow bug food chain is unknown, but no sow bugs were found in the contents of the 31 bird guts and 9 small mammal guts examined to date.

Open areas consist principally of former cattail areas that were not filled because they were above the target fill elevation. These areas were disced to eliminate tricolored blackbird habitat. As a result of discing, the organic sediment layer, which has elevated selenium levels, and cattail straw were mixed with underlying soil. A low growing groundcover, consisting mainly of clover, is colonizing this habitat type. Preliminary analysis of these plants show a geometric mean selenium concentration of 12.3 ppm (n = 12, range = 6.1-27). These high levels reflect the elevated levels in the substrate. Invertebrate samples from this habitat type are not yet available; however, they may also be expected to show elevated selenium levels.

Bird use of the Reservoir has changed substantially. Drying and filling of the Reservoir has made the site unattractive to nesting tricolored blackbirds and the aquatic bird species in which impacts have been observed in the past. Kesterson Reservoir is presently being used by terrestrial bird species such as meadowlarks, horned larks, killdeer, and sparrows. Elevated selenium levels were found in the livers and eggs of terrestrial bird species that were sampled. However, no selenium related embryotoxicity was found in the few nests of terrestrial bird species observed at Kesterson during the 1988 nesting season. The last bird death apparently related to selenium toxicosis at the Reservoir was a dead coot salvaged on July 1, 1988. No dead birds have been found at the Reservoir since that time.

Preliminary results of analysis of small mammals sampled at Kesterson during February 1989 indicate that whole body selenium concentrations are lower than those sampled in February of 1988. No adverse reproductive or growth impact to small mammals resulting from selenium has been observed at Kesterson Reservoir. Likewise, a study of racoons at the Reservoir found no adverse impacts from selenium. A study of the endangered San Joaquin kit fox found limited use of the Reservoir by this species and no negative effect of selenium levels at Kesterson Reservoir on kit fox. Two of eleven coyotes collected within Kesterson Reservoir as part of the kit fox study had liver selenium levels within the range associated with selenium toxicosis in domestic dogs, and one of these two showed clinical signs associated with selenium toxicosis. The coyotes were collected at Kesterson Reservoir at a time when aquatic habitats were still present and coyotes at the Reservoir were likely feeding upon dead and moribund coots suffering from selenium toxicosis. Because of the indications of selenium accumulation observed in the coyotes, however, kit fox use of the Reservoir continues to be monitored.

Anticipated Future Conditions at Kesterson Reservoir

This section describes anticipated future conditions with respect to ground water, surface water, and biota at Kesterson Reservoir assuming no further cleanup actions.

Ground Water

The Department anticipates that the few remaining plumes of seleniferous ground water will dissipate as the aqueous species are transformed to insoluble or strongly adsorbed species, and that selenium concentrations in the aquifer will remain low, due to a combination of geochemical/microbial and physical processes that restrict migration of selenium from the vadose zone into the underlying aquifer. The Department's research and ground water monitoring have demonstrated that chemically reducing conditions, created primarily by the mineralogical makeup of the aquifer sediments, favor the transformation and immobilization of dissolved selenium; in addition, downward leaching of selenium is opposed by strong evapotranspirative fluxes which bring soluble selenium inventories toward the soil surface during the summer months. At Kesterson, pan evaporation rates exceed 60 inches per year. The combination of high pan evaporation and the shallow depth of the water table lead to evapotranspirative fluxes that exceed the average annual precipitation by at least several inches. Therefore, on balance, the net flow of water is towards the soil surface. For these reasons, the Department does not expect any further selenium contamination of the ground water aquifer.

The plume of high TDS, boron rich water that seeped into the aquifer will dissipate very slowly as the regional flow of ground water carries it downgradient. The average ground water velocity is estimated to be on the order of 10 to 30 feet per year. Over many decades, the plume is anticipated to move to the north and northeast. However, future management of the Kesterson Refuge lands to the north and northeast of the reservoir could influence migration of the plume. For example, increased or permanent flooding of the Refuge lands could inhibit the velocity or affect the direction of migration of the plume.

Intermingling of the saline plume with the less saline native ground water will disperse and dilute the leading and trailing edges of the plume. Eventually, the plume will be discharged from the aquifer into regional sinks (Salt Slough and the San Joaquin River) and, by evapotranspirative transport, into the soils overlying the path of the plume. The rate of discharge into regional sinks will occur over such a long period of time and contribute such a minor fraction to the total load that it will be undetectable in the receiving surface waters.

Surface Water

Surface water ponding resulting from rainfall events is expected to occasionally occur at Kesterson Reservoir in the future, when rainfall exceeds both evaporative losses and seepage rates. Based on preliminary analysis, years with sufficient rainfall to fully saturate unvegetated Kesterson Reservoir soils and cause some surface ponding, principally in former Ponds 3, 4, and 6, are predicted to occur with a frequency of once in 3 to 4 years. On the order of once in 7 years, saturation and ponding might be expected over most unvegetated areas of the Reservoir.

Unvegetated, filled areas are expected to exhibit ponding more frequently than undisturbed regions of the Reservoir. This evaluation is based on the predominance of puddles in filled areas in comparison to unfilled areas during the current wet season. The currently observed puddles are a result of restricted rainfall infiltration through fill material. Natural revegetation of the filled areas will assist in preventing rainfall puddling in several ways.

Transpirative extraction of soil water during the hot summer months by plant roots increases the water storage capacity of the soil profile. Data from test plots at the Reservoir indicate that transpirative extraction provides storage space for about 2 to 4 inches of rainfall, depending on depth to the water table. Vegetative cover also reduces direct rainfall impact on the soil, such as dispersal of soil particles and clogging of soil pores. Thus, the infiltration capacity of the soil is maintained. Enhanced permeability throughout the soil profile is achieved through both the physical proliferation of roots and the

stabilization of aggregates by organic matter from root and microbial activity. Thus, as the filled areas become vegetated, the probability of rainfall ponding will be reduced.

Water quality of rainwater pools that may occur in the future will be a function of the salts and selenium present at the soil surface. Predictions concerning the redistribution of salts and selenium in Reservoir soils are, at this stage, tentative. Long-term forecasting of the Reservoir soil/water/plant environment, which strongly affects the salt and selenium distribution, will require a monitoring period sufficient to obtain time-trend data under relevant (i.e., non-ponded, filled) conditions. However, tentative projections can be made based on the expected implications of the general hydrologic environment, and a very limited set of data on the upland soil water environment at the Reservoir.

An important consideration concerning future redistribution of selenium and salts is the long term net upward movement of soil water. A trend of increasing salinity in the Reservoir soils will occur due to the influx of soluble salts from the shallow water table. Selenium redistribution in Reservoir soils is considerably more complicated than that of other soluble salts. Currently, only a small fraction of the Reservoir selenium inventory is found in soluble forms (approximately 15%). With conversion of the Reservoir to a dry, upland environment, oxidation of the previously insoluble inventory is expected to take place over time. Thus, more selenium will be found in one of several mobile forms, susceptible to evaporative concentration, plant uptake, volatilization, and leaching. Most transformations of the present selenium inventory at the Reservoir are expected to take place slowly. Observations over the past 2 years in nonponded soils suggest that, while seasonal oscillations in selenium partitioning occur, major changes in the inventory are likely to require time scales from years to tens of years.

On an even longer time scale, the selenium inventory within the shallow vadose zone is expected to be diminished through the two slow processes of natural volatilization and deeper leaching to below the annual minimum water table elevation. Under unmanaged conditions, selenium volatilization is expected to be slow due to a soil environment which is not conducive to rapid biological cycling. In particular, the surface soil is expected to be very saline, relatively dry, and low in readily decomposable organic matter. Periodic leaching from the vadose zone to below the water table is possible, as suggested from monitoring data from an unvegetated plot in Pond 9. While single episodes of leaching are relatively ineffective in moving selenium deeper into the profile, the cumulative effect of this mechanism over the long term may contribute significantly to depletion of the inventory from the vadose zone. Selenium leached from the vadose zone will

be transformed to insoluble forms and immobilized in the region below the minimum annual elevation of the water table.

All of these considerations preclude any confident prediction of future water quality in rainfall pools. At present, soluble selenium in bare soil (unfilled) surface crusts at the Reservoir have had concentrations in the range of 10 to 20 mg per square meter of crust. Such concentrations, susceptible to dissolution in rainfall pools, would easily exceed the surface water quality goal of 2-5 ppb. However, some fraction of this inventory leaches into the soil before the puddle forms, decreasing the concentration in the pool. Nevertheless, due to the large inventory of soluble selenium, the Department anticipates that a significant fraction of the rainwater puddles will have selenium concentrations in excess of the 2 to 5 ppb surface water goal. With increasing surface inventories of soluble selenium and salts, as is predicted in the above discussion, the potential for these puddles to exceed surface water goals will persist. However, it is important to note that in years where extensive ponding occurs at the Reservoir, surface water concentrations will be lower due to a large dilution factor created by heavy rains.

Biota

It is expected that selenium levels in wildlife that use grassland habitats at the Reservoir will be similar to, or lower than, the levels observed at present. Elevated levels of selenium have been found in terrestrial bird food items and bird livers and eggs. However, no adverse impacts were observed in the limited number of nests of terrestrial birds that have been examined to date. Also, no adverse impacts to small mammals or racoons have been found in studies of these species. All adverse impacts observed in the past at Kesterson Reservoir have been directly associated with wetland food chains or, as in the case of coyotes, the wetland food chain is at least implicated. However, research and monitoring emphasis has only recently focused on the terrestrial food chain and sufficient data is unavailable to determine whether the elevated selenium levels observed in the grassland biota will result in adverse wildlife impacts in the future.

The expectation that selenium levels may be lower in the future in grassland biota is based on the fact that over 700 acres of the Reservoir are covered with fill material. Whereas in the past grassland species may have occasionally foraged in adjacent wetland habitats with high selenium levels, these species may now occasionally forage in adjacent filled areas. This may result in overall lower selenium levels in the grassland species. The preliminary data from small mammals collected in February, 1989,

which show selenium levels much lower than those collected in February, 1988, may be an indication of this effect.

Preliminary analysis indicates that selenium levels are low in the annual grasses that are presently colonizing the filled areas at the Reservoir. It is expected that all soils at Kesterson will eventually become saltier and that this increased soil salinity will place constraints on plant growth, both in terms of species and productivity. The fill material is expected to undergo the same longer-term accumulation of salts and selenium. This process will eventually lead to conditions in the filled areas which parallel those currently being observed in unfilled regions. Salt grass, able to withstand highly saline soils, is expected to invade the filled areas and be the predominant plant throughout the Reservoir. It is expected that the filled areas will eventually become similar to the present grassland habitat at the Reservoir, except for the litter layer. The selenium levels in the litter layer of current grassland habitats is believed to be a result of deposition of organic material during past flooding of grassland habitats with drainwater. The selenium levels in the litter layer that may be present in filled areas in the future would be expected to be no higher than observed in the grassland plant species.

Preliminary analysis of vegetation colonizing the open disced-cattail habitat indicates higher selenium levels than that found in the grassland or filled habitats. These high selenium levels are apparently related to the high soil and organic matter selenium levels found in the open habitat. It is unknown whether the open habitat, left unmanaged, will result in adverse wildlife impacts.

Hydrologic analysis indicates that, although ground water is not expected to rise high enough to form ephemeral pools, soils will saturate and puddles will form in high rainfall years. Although selenium levels are not anticipated to be nearly as high as observed in ephemeral pools formed by rising ground water observed in the past, levels may be high enough to result in elevated levels of selenium in aquatic plants and invertebrates. Observations in the winter of 1988-1989 indicate aquatic biota might begin to grow in pools that are present longer than about one month in the late winter/spring. Left untreated and unmanaged, aquatic birds could use the pools for feeding and could potentially become exposed to elevated levels of selenium.

RECOMMENDED CLEANUP PLAN

As noted earlier in this document, two significant cleanup actions have been completed at Kesterson Reservoir which have effectively eliminated the threat of offsite selenium contamination and have broken the exposure pathway which has been demonstrated to cause significant wildlife impacts in the past. In evaluating what further cleanup actions should be taken at Kesterson Reservoir, the Department of the Interior has considered the following factors:

- No adverse impacts to wildlife have been detected through the terrestrial food chain at Kesterson Reservoir although elevated levels of selenium occur.
- Wetland habitat has been essentially eliminated at the site.
- Offsite migration of selenium, either into surface waters or into the ground water aquifer, will not occur.
- Despite substantial efforts, no short-term selenium removal technology has yet been demonstrated, short of excavating and disposing of over 9,000,000 cubic yards of material.
- Persistent rainwater puddles have been observed at the Reservoir and could potentially form an aquatic exposure pathway for selenium contamination.
- There remains a substantial selenium inventory at Kesterson Reservoir and evapotranspirative fluxes will, over time, tend to concentrate selenium as well as other salts in the soil surface and root zone.
- During years of unusually heavy rainfall, substantial surface puddles are likely to be present at Kesterson Reservoir potentially reestablishing, albeit temporarily, aquatic exposure pathways for selenium contamination.

From these considerations, the Department has concluded that the soil selenium inventory at Kesterson Reservoir requires continued management to avoid potential threats of future wildlife contamination at Kesterson Reservoir. Short of excavating and disposing of more than 9,000,000 cubic yards of material to remove the majority of the remaining selenium inventory, effective short-term means to remove the inventory have not yet been identified despite the Department's substantial investigations. The Department does not consider such a large-scale earth removal action to be either feasible or prudent as a management strategy. Instead the Department proposes to implement a plan with the following three components: active site management to eliminate exposure pathways and minimize potential impact; continued monitoring of water and biota to verify lack of impacts and identify potential specific exposure pathways; and continued research into effective means of dissipating the selenium inventory at Kesterson Reservoir.

Site Management

Kesterson Reservoir will be actively managed to minimize potential impacts to wildlife and ground or surface waters from selenium contamination. Yearly management actions will be determined through interaction with the monitoring and research components. Specific management actions to be taken this year, prior to the 1989-90 wet season, will be directed at potential exposure pathways associated with persistent rainwater puddles and elevated levels of selenium apparent in vegetation invading the open areas.

Treatment of the identified persistent rainwater puddle areas will be dependent on the cause of puddling. Where the puddles have been due to topographic irregularities the area will be graded and, if necessary, spot filled. Where the puddles have been due to infiltration problems, the area will be disced and/or gypsum added to enhance infiltration.

The open areas will be disced. These areas have high selenium levels and discing will minimize biological productivity and potential habitat, and thus minimize or eliminate potential contamination pathways.

Future management aCtions will be dictated by monitoring and research activities. If adverse impacts associated with the terrestrial food chain are identified, specific actions will be taken to break the exposure pathway. In years of heavy rainfall, any standing surface water at the Reservoir will be intensively monitored. If food chain items become established and have selenium concentrations in excess of established trigger levels, hazing will be implemented. The Department will use the same trigger level that is applied to management of standing surface water elsewhere in the San Joaquin Valley. This level is currently 8 ppm selenium; however, the Department recognizes that the level may be modified in the future and will use whatever level is then currently established.

An annual management plan will be prepared, and it is proposed that this plan be submitted along with other monitoring reports routinely provided to the Regional Water Quality Control Board. The annual management plan will detail specific management actions to be taken in the upcoming year in response to observations made as part of continued monitoring and research activities.

Monitoring

An intensive monitoring program is ongoing at Kesterson Reservoir and will be continued. Monitoring of water quality and biota is designed to detect any adverse effects from contamination at Kesterson Reservoir as well as any migration of contaminants

offsite. The Department will continue to provide the results of its monitoring routinely to the California Regional Water Quality Control Board - Central Valley Region, as specified in Monitoring and Reporting Program No. 87-149. Since dewatering of the Reservoir and filling of ephemeral pools, the emphasis of the biological monitoring has shifted to detection of any adverse effects to wildlife associated with the dry habitats now present at Kesterson Reservoir. Continued emphasis will be placed on this effort to verify the lack of impacts associated with the dry land habitats. In addition, in the event of heavy rainfall resulting in surface water at the Reservoir, intensive monitoring will be implemented in order to rapidly identify any potential aquatic exposure pathways.

Research

Research into effective long-term dissipation techniques for the selenium inventory at Kesterson Reservoir will continue. Dissipative processes for removing selenium from the Kesterson soils include microbial volatilization from soils, volatilization from plants, plant uptake, molecular diffusion, and leaching. These processes will very slowly decrease the inventory at the Reservoir. An active research program being conducted at Kesterson Reservoir through a collaboration of scientists from the Lawrence Berkeley Laboratory and the Division of Agricultural and Natural Sciences of the University of California system is seeking to identify means to accelerate these processes. From the research results to date, the Department anticipates that the eventual dissipation of the selenium inventory will be a long-term process. Current estimates are that microbial volatilization techniques may require up to 10 years to dissipate the surface inventory. Alternative techniques of soil/water/vegetation management to enhance natural volatilization as well as other dissipative processes are currently estimated to require 10 to 20 years to dissipate the inventory. Data from field trials are not sufficiently complete to warrant large scale implementation of any of these processes. If research identifies feasible site-management actions that can accelerate the dissipative processes while minimizing risks to wildlife, such management actions will be incorporated into the Kesterson Reservoir management.

SUBCHAPTER 15 PROVISIONS

State Board Order No. WQ 88-7 states, in part: "The [cleanup plan] report shall demonstrate that the final cleanup plan can be approved, under Section 2510 (b) of Subchapter 15, as an alternative to the closure requirements for a surface

impoundment." (Order at page 40, paragraph 4). Section 2510 (b) of Subchapter 15 states:

> Unless otherwise specified, alternatives to construction or prescriptive standards contained in this subchapter may be considered. Alternatives shall only be approved where the discharger demonstrates that:
>
> (1) The construction or prescriptive standard is not feasible as provided in subsection (c) of this section, and
>
> (2) There is a specific engineered alternative that
>
> (A) is consistent with the performance goal addressed by the particular construction or prescriptive standard, and
>
> (B) affords equivalent protection against water quality impairment.

Subsection (c) of Section 2510 states:

> To establish that compliance with prescriptive standards in this subchapter is not feasible for the purposes of subsection (b) of this section, the discharger shall demonstrate that compliance with a prescriptive standard:
>
> (1) Is unreasonably and unnecessarily burdensome and will cost substantially more than alternatives which meet the criteria in subsection (b) of this section; or
>
> (2) Is impractical and will not promote attainment of applicable performance standards.
>
> Regional boards shall consider all relevant technical and economic factors including, but not limited to, present and projected costs of compliance, potential costs for remedial action in the event that waste or leachate is released to the environment, and the extent of ground water resources which could be affected."

The basic prescriptive standard for closure of a surface impoundment, as specified in Section 2582, is the removal of all residual wastes and contaminated geological materials and disposal in an appropriate management unit, or, closure of the unit as a landfill.

<u>(1) Feasibility of Prescriptive Standard</u>

Removal of all residual wastes and contaminated geologic material at Kesterson Reservoir would require excavation to depths ranging from 3 to over 10 feet (Declaration of Sally Benson, in the Department's Pre-Hearing Submission to State Water Resources Control Board in Support of Modification of Order No. WQ 87-3 Concerning Cleanup Plan for Kesterson Reservoir, submitted May 16, 1988 ("Pre-Hearing Submission"), at Volume 1, Section C.1). Excluding the new fill material that has been placed in the Reservoir, an estimated 8,300,000 cubic yards of material would have to be excavated and disposed of at an estimated cost of $150 million, assuming disposal in a constructed onsite facility

(Declaration of Alan W. Stoppini, in the Pre-Hearing Submission, at Volume 1, Section C.5). If the material were disposed of in an offsite facility, costs would be substantially higher as indicated by the comparative analysis of onsite and offsite disposal options reported in the Kesterson Program Final Environmental Impact Statement (FES 86-42), at Tables 3-10 and 3-12. Again, the Department's previous cost estimates do not take into account the addition of the more than one million cubic yards of material recently placed in the Reservoir.

Section 2582 (b)(1) alternatively provides for the closure of a surface impoundment as a landfill facility pursuant to Section 2581, "[i]f, after reasonable attempts to remove such [natural geologic] contaminated materials, the discharger demonstrates that removal of all remaining contamination is infeasible." Because the Department plans to rely on in situ processes to control residual contamination at Kesterson Reservoir, rather than to remove contaminated geologic materials, this provision of section 2582 in not pertinent. Moreover, as is indicated in section 2581, another premise for the applicability of this provision is that the surface impoundment was constructed with certain protective features such as a leachate collection system. Kesterson Reservoir, as constructed, does not include those features.

The provisions of Section 2581(b)(2) also are inapplicable to Kesterson Reservoir. Under these provisions the closed waste management unit must meet applicable standards for landfill waste management units in Articles 3 and 4 of the Subchapter. Section 2581 and Articles 3 and 4 contemplate a facility constructed with certain protective features such as liners, a leachate collection system, protective cover, and other constructed features. Closure of Kesterson Reservoir as a landfill is not feasible because Kesterson Reservoir, as it was designed and built, does not meet article 3 and 4 standards for a Class II landfill for designated waste disposal.

For the preceding reasons, the Department concludes that the application of the standard prescriptions for closure of a surface impoundment would be unreasonably and unnecessarily burdensome in the context of the residual contamination at Kesterson Reservoir. As is discussed below, the Department's cleanup plan presents an engineered alternative that will satisfy the criteria of section 2510(b) for substantially lower costs.

(2) Engineered Alternative

The Department already has taken major action -- i.e., the filling of low-lying areas -- to control the most significant potential source -- i.e., rising ground water -- of further adverse environmental effects from residual contamination at Kesterson Reservoir. This action, together with the additional

control actions planned by the Department, meet the criteria of section 2510(b) for approval of an engineered alternative.

(A) Performance Goal.

In its Order No. WQ 87-3, at page 16, the State Board characterized the performance goal of section 2582 as follows:

> A major goal of Subchapter 15 is "the prevention of [waste] discharges to ground water"......
> The administrative record of the adoption of Subchapter 15 indicates that the performance goal of Section 2582, in keeping with the overall discharge prevention goal of the subchapter, is to prevent the escape of residual wastes from a surface impoundment upon closure.

The Department already has demonstrated by substantial evidence that natural geochemical and microbial processes at Kesterson Reservoir effectively preclude the migration of selenium in the ground water underlying the Reservoir in the absence of nitrate, and that the termination of drainwater disposal at the Reservoir eliminated the sources of nitrate that was shown to be inhibiting these natural immobilization processes. (Pre-hearing Submission at Volume 2, Section A, and Volume 4, Section A). The State Board recognized these circumstances in Order No. WQ 88-7, at page 31: "The Board has found that ground water pollution is not a significant concern."

The other potential avenue for migration of residual contamination in water from the Reservoir is through the runoff of surface water. This avenue is effectively blocked by the remaining exterior dikes of the Reservoir, which were constructed to provide 100-year flood protection for the site.

For the preceding reasons, the Department concludes that the performance goal of Section 2582 has already been achieved at Kesterson Reservoir. The further cleanup actions planned by the Department will not interfere with this achievement.

(B) Equivalent Water Quality Protection

The achievement of the performance goal of section 2582, as described above, has assured continuing equivalent protection against any further impairment of water quality outside of Kesterson Reservoir. Within Kesterson Reservoir, the potential for significant surface water formation has been virtually eliminated for dry and normal water years. Impacts to wildlife observed at Kesterson Reservoir in the past have been associated with the aquatic food chain which has been effectively broken by the actions to maintain the Reservoir in a dry condition. No adverse impacts associated with the dry habitat ecosystem at Kesterson Reservoir have been demonstrated.

The Department recognizes that, in years of high rainfall, some surface ponding in Kesterson Reservoir will occur. However, the mechanism for the occurrence of the high levels of selenium contamination observed in ephemeral pools at Kesterson Reservoir -- i.e., rising ground water -- has been eliminated by the filling of the ephemeral pool areas. The mechanism that could result in surface ponding at the Reservoir in the future is from rainfall.

Rainwater will dissolve salts and selenium accumulated on the surface. Following episodes of normal rainfall, however, any surface accumulations of water are not likely to persist long enough to generate significant aquatic biota and, therefore, will not pose a material risk to wildlife. During prolonged periods of heavy precipitation, leaching will tend to drive soluble salts and selenium downward into the soil, minimizing the inventory available for dissolution into the rainfall pools. Furthermore, the relatively large quantity of surface water under such circumstances will tend to provide a greater diluting effect resulting in lower total concentrations in the surface water.

In the Department's view, the provision in section 2510(b) for "equivalent protection against water quality impairment" is not applicable to occassional accumulations of rainfall in an upland environment. However, the Department's cleanup plan does in effect provide for equivalent protection with respect to potential wetland habitat through continued actions to prevent the reestablishment of any such habitat within Kesterson Reservoir. Actions will be taken this year to eliminate the few remaining areas where surface accumulations of rainfall have persisted during the current winter period. If in future years heavy rainfall unavoidably results in surface ponding, the Reservoir will be closely monitored to provide early detection of any potential contamination pathways that might otherwise become established. Should exposure of wildlife to contamination be threatened, hazing will be implemented.

For the preceding reasons, the Department concludes that its cleanup plan will satisfy the provision of section 2510(b) for equivalent protection against water quality impairment.

ACHIEVEMENT OF CLEANUP GOALS

State Board Order No. WQ 88-7, at page 40, paragraphs 4-5, states: "The [cleanup plan] report must demonstrate, at a minimum, implementation of the final cleanup plan will achieve cleanup goals at Kesterson in a timely manner.... The Bureau shall be given no later than April 1, 1990, to achieve cleanup goals under the final cleanup plan."

The State Board did not specify the intended "cleanup goals" in Order WQ 88-7. The Department presumes that the State Board intended to refer to the surface water goal of 2-5 ppb and food chain goal of 3 ppm selenium, originally proposed as target goals under the Department's Phased Approach Cleanup Plan submitted in December, 1986. It should be recognized that the Department adopted these target goals in relation to the wetland habitat environment that the Department was then proposing to maintain at Kesterson Reservoir. As is described below, the Department therefore has reevaluated these target goals in relation to its current cleanup plan.

Although the food chain goal of 3 ppm was established based on wetland habitat species, a lack of research evidence to the contrary supports the continued use of this goal in the context of the upland environment that the Department now plans to maintain at the Reservoir. The Department therefore plans to use this goal in the continuing evaluation of monitoring and management actions at Kesterson Reservoir. However, the Department knows of no reasonable action that can be taken to achieve this goal by the date -- April 1, 1990 -- specified in the Order at page 40, paragraph 5.

As an operative goal until Kesterson Reservoir can be determined safe and returned to productive beneficial use, the Department plans to act to avoid all significant biological effects of contamination at Kesterson Reservoir. Detection of biological effects will focus primarily on nesting birds as, based on current knowledge, such birds are the most sensitive indicator of adverse impacts of contamination. Intensive monitoring of nesting birds at Kesterson Reservoir will be conducted and evidence of biological effects will consist of embryo mortality, teratogenesis, or nesting failure attributable to contamination. Sampling efforts will also be focused on detecting any evidence of reproductive effects of contamination in small mammals, and evidence of adverse effects in predatory species using the site.

Biological data will be reviewed annually with biologists and researchers from the Fish and Wildlife Service to determine whether the operative goal is being achieved. Based on the results of the biological studies, appropriate management actions will be incorporated and implemented as part of the subsequent annual management plan for the Reservoir.

It is the ultimate goal of the Department to return the Kesterson lands to productive use. Until this goal can be realized, the Department will discourage wildlife use of the Reservoir habitat.